THE

GEOLOGICAL MAGAZINE

VOLUME LVII.

No. V.—MAY, 1920.

EDITORIAL NOTES.

THIS month our Editorial notes are shorter than usual, owing to pressure of other matter on our space, especially somewhat lengthy correspondence, which has to some extent upset the original programme and caused one or two papers to be unavoidably held over. Furthermore, the incidence of the Easter holidays has made it difficult to keep up with current events in the geological world.

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IN the long list of recipients of various grades of the Order of the British Empire we are glad to notice the names of some geologists, though few in number. They are as follows: Mrs. Shakespear, Dame B.E.; Dr. F. H. Hatch, O.B.E.; Mr. J. Allen Howe, O.B.E.; Miss G. L. Elles, M.B.E.; Mr. H. T. Burls, M.B.E. We are by no means sure whether the first item on this list is correctly expressed; if not, we offer apologies.

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AT the annual meeting of the Prehistoric Society of East Anglia, held at the rooms of the Geological Society on March 23, Professor J. E. Marr delivered his Presidential Address, which dealt mainly with the relationship of the deposits containing human relics to the Glacial period. He considered that as the result of Mr. Reid Moir's discoveries the existence of Pliocene man in Britain has been proved. After noting the possible existence of glacial conditions in this country in late Pliocene times, he devoted the main portions of the address to the Pleistocene period. He regards the evidence as favouring the occurrence of a glaciation (the Cromer Drift glaciation) at the beginning of the Pleistocene period, followed by genial conditions during Chellean and Acheulean times. After this followed the glaciation which caused the formation of the Chalky Boulder-clay, which coincided generally with Lower Mousterian times. A slight rise of temperature occurred during Upper Mousterian, Aurignacian, and Solutrean times, though not necessarily sufficient to cause the ice to disappear from more northerly parts of our Island, and during the Magdalenian period the ice re-advanced southward to some extent. If the period from Lower Mousterian to Magdalenian

times be regarded as marked by only one glaciation, it would appear that the Chelles–Acheul period immediately preceded the last glaciation, a view in harmony with that of the latest Continental writers. Professor Marr's views are largely based upon Mr. Moir's discoveries in the Ipswich area, but he brought confirmatory evidence from other places. The latter part of the address dealt briefly with changes of sea-level during the times when man dwelt in Britain, and allusion was made to certain river-diversions which were brought about in the same times. The President concluded by emphasizing the vagueness of some of our interpretations, and urgently advocated the collection of more facts, a task which the members of the Society had already largely undertaken during the few years of the Society's existence.

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At the meeting of the Geological Society of London on March 21 the President announced that the Council had awarded the Proceeds of the Daniel Pidgeon Fund available in the present year to Miss Marjorie Elizabeth Jane Chandler, who proposes to investigate the Oligocene Flora of the Hordle Cliffs (Hampshire), and to Laurence Dudley Stamp, B.Sc., Assoc.K.C.L., F.G.S., who proposes to make a comparative study of the Downtonian and Gedinnian in North-Western Europe.

We have received the following letter from a valued correspondent, too late for insertion in the ordinary place in the Magazine, so we venture to put it in our Editorial Notes instead:—

Sir,—I believe the following couplet was written about the time of the publication of Buckland's Bridgewater Treatise on Geology. Could any of your readers give me the author's name?

> All, all, was dark and drear before the *Flood*,
> Till Buckland came, and made it *clear as mud!*

X Y Z.

Addendum to Obituary Notice of R. Etheridge, jun. (*p.* 240).

Mr. R. Bullen Newton, F.G.S., of the British Museum (Natural History), London, S.W. 7, writes: "An excellent notice of R. Etheridge, jun., appears in the *Sydney Daily Telegraph*, written by Professor Edgeworth David, F.R.S. So far as I can trace, R. E., jun., was a member of the Royal Society of New South Wales, an Honorary Fellow of the Royal Society of South Australia, and a Corresponding Member of the Royal Society of Victoria. In past years he had been a Fellow of the Geological Society of London, and had also been President of the Royal Physical Society of Edinburgh. At the time of his death he was a member of the Malacological Society of London."

Charles Lapworth: an Appreciation.

AS announced in our April number, Professor Charles Lapworth died at his residence, Edgbaston, Birmingham, on March 13.

For an account of his life and work our readers are referred to an article—one of the "Eminent Living Geologist Series"—which appeared in the July number of the Magazine in the year 1901. At the time when that article was written the main results of his work in the field, the outcome of thirty-three years of labour, had already been published, and we need therefore add but little to its records.

In 1902 he was elected President of the Geological Society, a position which he would certainly have occupied many years before that date had circumstances permitted. In the following year he delivered his presidential address to the Society, to which further allusion will be made presently. Unfortunately illness prevented him from retaining the Presidency for the usual two years, and geologists were accordingly deprived of a second address, which would doubtless have attained the high level of that which was actually delivered.

In the year 1902 he was also appointed a member of the Royal Commission to inquire into the coal resources of this country, and the importance of his contributions to the report of the Geological Committee of that Commission on the resources of the concealed and unproved coalfields, published in 1905, is widely recognized.

His work on applied geology became more varied as time advanced, and he was in great request as a consulting geologist on questions which concern the miner, the engineer, and others. The city of Birmingham in particular was indebted to him for work of this character, with the result that the hard-headed business-man was taught the value of geology in a manner which specially appealed to him.

Among the later honours conferred upon him we may mention the honorary degree of LL.D. of the University of Glasgow in 1912, and the award of the Wilde Medal of the Manchester Philosophical Society in 1905. We would note, also, that since our former account of Lapworth was published, the monograph of the British graptolites, by Miss Elles and Mrs. Shakespear, has been completed. It forms a fitting conclusion to his great work on this group of organisms, for, as its authors fully admit, it was inspired by Lapworth and he superintended its production throughout.

In attempting an appreciation of Lapworth's life-work, it must be stated at the outset that he was pre-eminently a stratigrapher and field-geologist, though he utilized all branches of geology in pursuing his work, and in so doing added materially to our knowledge of them. His work on the Lower Palæozoic rocks of the Southern Uplands of Scotland forms the foundation upon which his later

work was based, and the unravelling of the complex of those uplands was logically followed by that of the much greater complex of the North-Western Highlands.

At the outset he found that field-work in the Southern Uplands required to be supplemented by study of the fossil evidence, and accordingly devoted himself so assiduously to the study of the graptolites that he rapidly became the leading authority upon this group of organisms, and remained so to the day of his death. In acquiring his knowledge of these animals, he mastered the biological memoirs treating of their nearest living allies, and thus incidentally trained himself as a first-rate palæontologist. How accomplished he was as such was later shown by his ingenious restoration of the structure of the trilobite, *Olenellus* (*Callavea*) *Callavei*, from study of the imperfect fragments which he discovered in the Cambrian rocks of Comley.

Again, when solving the riddle of the North-West Highlands, various petrographical questions confronted him, and his study of petrology enabled him here to contribute much to our knowledge of the processes of metamorphism.

The severe illness developed as the consequence of his work in the Highlands had a permanent effect upon Lapworth, and brought to a close the strenuous days of his field-work. Although he subsequently accomplished much among the old rocks of the classic region of Siluria and elsewhere, the work was not marked by the intense vigour which characterized the prosecution of his earlier labours. When we recognize that in his earlier years he was hampered by want of leisure, and in his later by lack of health, we are amazed at what he actually performed.

But though his field-work was impeded in later years, the activity of that most original mind was unimpaired. Lapworth's early training in geometry always stood him in good stead, and enabled him readily to visualize in three dimensions. His work in the Uplands and Highlands of Scotland aroused his interest in tectonic problems, and led to the elaboration of his fold theory. He treated of this at much length in his Presidential Address to the Geological Section of the British Association at Edinburgh in 1892, and finally turned to it once again in that part of his Presidential Address to the Geological Society which deals with geology and physics. Many of the sentences in this are pregnant with meaning, and give us a glimpse of the workings of the mind of a seer. How one regrets that he had neither time nor opportunity to write a great work upon theoretical geology embodying his riper conclusions!

Those who wish to gain a just idea of Lapworth's work should read not only the account given in this Magazine in 1901 but also his own address to the Geological Society. Parts of that address may be regarded as autobiographical, for when he writes of the varied duties of a geologist he is often unconsciously describing his own methods of work in research, scientific practice, and education.

We claim Lapworth as one of the foremost geologists of all time. His output of published work must be estimated by quality rather than quantity, for there is no doubt that his ill-health of later years prevented him from publishing as fully as would otherwise have been the case.

The profound influence exerted by what is published is generally realized, and we need dwell no longer upon this part of his work. But much of his knowledge which he did not commit to print is not lost, but is bearing fruit, and will continue to do so. For Lapworth was a great teacher, and his students have proved this in many ways. His influence, however, was not by any means confined to the lecture-room, and during the years of his Professoriate at Birmingham the city was a geological Mecca, where geologists of all classes went to discuss their work with one who was always ready to help, and they ever came away enriched with new ideas, which will aid materially in swelling the stock of geological knowledge.

Many of us will recall the evenings when, after a hard day's work in the examination-room or elsewhere, and having partaken of a cheerful dinner, Lapworth would perhaps sit down at the piano and play his accompaniment to some gay song from the latest popular opera, and the listener would think that the day's work was over, until a move was made to the study and the Professor poured out treasures from the storehouse of his mind until the small hours of the morning, and the brain of the awed listener reeled. Or, after the consumption of the midday sandwiches on some mountain-slope, he would explain the structure of the surrounding country during the frequent intervals between the relighting of his pipe, until its aspects during the different geological periods seemed to glow before the hearer's vision.

Experts and tyros alike have had these experiences, sitting at the feet of the master. This was, indeed, a liberal education, and one which will prevent his unpublished ideas from being for ever lost. How sad it is to realize that the experiences are now things of the past! But the memories of them are dear, and we treasure the recollection of the waves of joy and earnestness alternating on his animated face, like the changes of light and shade on a hillside beneath a dappled sky.

Would that we could present a faithful picture of him to those who had not the privilege of knowing him, but the task is impossible. We have lost a great geologist, and withal a man of very beautiful character.

ORIGINAL ARTICLES.

Intra-Jurassic Movements and the Underground Structure of the Southern Midlands.

By Professor Arthur Hubert Cox, M.Sc., Ph.D., F.G.S., and Arthur E. Trueman, D.Sc., F.G.S., University College of South Wales and Monmouthshire, Cardiff.

I. Introduction.

RECENT investigations into the relationship between geological structure and magnetic disturbance have called attention to the existence of a line of anticlinal folding that affects the Triassic and Lower Jurassic rocks in the neighbourhood of Melton Mowbray, Leicestershire.[1] It has further been shown to be highly probable that this post-Triassic anticline follows and is founded upon the line of an older and more pronounced anticlinal uplift of pre-Permian date.[2] The presence of the post-Triassic anticline is indicated on the geological map by the sudden swing round of the outcrops of Triassic and Liassic rocks from the normal north to south (or N.N.E. to S.S.W.) direction into a north-west to south-east direction, and then back again to the normal (N.N.E. to S.S.W.). The sudden change of strike is noticeable in the outcrops of all the formations from the Keuper Marl to the Inferior Oolite inclusive, but it becomes least apparent and is gradually lost in the succeeding divisions of the Middle Jurassic. This suggests that the movements that gave rise to the anticlinal structure had died down during or prior to the deposition of the Bathonian rocks.

A similar swing is seen in the Vale of Moreton, and again in the north Cotteswolds, and these were shown by Mr. S. S. Buckman to be due to anticlinal and synclinal folding;[3] the same writer has repeatedly shown by his detailed zonal studies that the Inferior Oolite and other divisions of the Jurassic rocks frequently show evidence of anticlinal flexuring and penecontemporaneous erosion.[4] For instance, he showed that the sequence of the Upper Liassic zones is complete, or nearly so, at Bredon Hill, which is situated on a synclinal axis, while elsewhere non-sequences frequently occur, especially along lines of anticlinal folding. He has further suggested that movement has occurred along many of these lines at intervals during Mesozoic and even Tertiary times.[5]

[1] Cox, "A Report on Magnetic Disturbances in Northamptonshire and Leicestershire and their Relations to the Geological Structure": Phil. Trans., ser. A, vol. 219, 1919, Appendix, pp. 73–135.

[2] Loc. cit., p. 122.

[3] Buckman, "The Toarcian of Bredon Hill": Quart. Journ. Geol. Soc., vol. lix, 1903, p. 449.

[4] A list of Mr. Buckman's chief papers on these subjects is given in Quart. Journ. Geol. Soc., vol. lxvi, 1910, p. 53.

[5] Op. supra cit., 1903, p. 449.

Mr. L. Richardson has since shown that some of these folds, notably those in the northern Cotteswolds, at Bredon and Moreton, are indicated also by the Rhætic rocks, which attain a great development at Dunhampstead, on the line of the Bredon syncline, and which show a non-sequence at Church Lawford, in the Vale of Moreton, along the anticlinal flexure. Richardson also stated that the Moreton anticline was probably a continuation of the Pennine axis.[1]

II. Other Possible Anticlinal Axes.

Examination of the geological map discloses the existence of other localities where the outcrops of the Liassic rocks suffer a local twist from what one may regard as the normal north-easterly to south-westerly strike. Such swings are noticeable at the following localities taken in order from north to south:—

1. Melton Mowbray.
2. ? Market Harborough.
3. Weedon.
4. Banbury.
5. Vale of Moreton.
6. Winchcombe.

But whereas the anticlinal structure has been definitely shown to exist, as noted already, at several of these localities, it has not been proved in the remaining cases. Yet, judging by analogy, it at once appears probable that the places mentioned are situated on or near the lines of anticlinal axes. In the following pages the available evidence as to the existence of such lines is examined, the age of the movements is considered, and the possible bearing of the flexures upon the deep-seated structures is discussed.

It is at once apparent that the postulated anticlines are not equally well developed, but that the flexuring is most powerful in the case of the two western anticlines, the Vale of Moreton and the Winchcombe folds. In these two cases the outcrops are twisted to such an extent that further evidence of the presence of anticlinal folding is hardly needed. These anticlines are evidently structures of considerable magnitude, and each is clearly accompanied by its complementary syncline, the Chipping Campden syncline and the Bredon syncline.[2] But in the case of the other anticlines mentioned above, the evidence from the map is not so clear, and additional evidence is needed before the anticlinal character of the respective localities can be considered as established.

One reason for the necessity of further evidence is that each of the postulated anticlines through Banbury, Weedon, and Market Harborough respectively, is related to the line of a river valley or valleys; the combination of river valley, horizontal strata, and relatively high relief might suffice to explain in each case the local

[1] Richardson, "The Evidence for a Non-Sequence between the Keuper and Rhætic Series in North-West Gloucestershire, etc.": Quart. Journ. Geol. Soc., vol. lx, 1904, pp. 349–58.

[2] The Bredon syncline, as Mr. Buckman has shown, is a prolongation of the Cleeve Hill syncline (Buckman, op. cit., 1903).

bending of outcrops without the aid of any anticlinal flexuring. On the other hand, the existence of the valleys may be significant when account is taken of the known preference of river valleys for anticlinal areas, as instanced by the anticlines already proved through Melton Mowbray and the Vale of Moreton.

Although the outcrops of the various members of the Lower Jurassic, particularly the Lower and Middle Lias, suffer marked deviations in the valleys mentioned above, it is noticeable that the outcrops of the Middle and Upper Jurassic rocks are not affected in any way. This at once suggests that the flexuring took place during Jurassic time, and that the movements had died down prior to the deposition of the Cornbrash and Oxford Clay.

If such intra-Jurassic folding has occurred it would give rise to non-sequences along the anticlinal axes, while in the complementary synclines the succession should be more nearly complete. This has proved to be the case wherever the strata have been sufficiently studied, as in the Vale of Moreton anticline and the Bredon syncline, investigated by Buckman.

III. Further Evidences of Intra-Jurassic Movement.

In attempting to use zonal methods to demonstrate the existence of Jurassic folding in the area between the Vale of Moreton and Melton Mowbray, we are unfortunately met by a great lack of detailed information which can be regarded as trustworthy in the light of recent refinements of zonal work. Further, it has frequently happened that the thickness of a subdivision or zone as determined at *one locality* has been quoted as the thickness throughout a *whole county*. In point of fact, thicknesses may vary greatly within the county limits. For these reasons we have been unable to use many of the figures that at first sight would appear to be available. Owing to this lack of reliable information only certain well-marked zones can at present be used for our purpose.

It is obvious that non-sequences and local variations in thickness will show best in thin zones. Further, the most useful deposits will be those which were laid down after periods of considerable movement; thus Mr. Buckman has found that some of the most notable non-sequences correspond with the Bajocian uplift and denudation.[1] During the deposition of the Lias, the maximum movement occurred between the times of accumulation of the Middle and Upper Lias, that is after the hemera of *spinati*, when slight uplift took place, and gentle folding resulted in the formation of several shallow basins in which first a thin deposit of the Transition Bed (*acutum* zone) and then the lower zones of the Upper Lias were laid down.[2] These beds would naturally be absent or very

[1] Buckman, "The Cleeve Hill Plateau": Quart. Journ. Geol. Soc., vol. lviii, 1897, pl. xlvi; and also "The Bajocian of the North Cotteswolds": ibid., vol. lvii, 1901, p. 146.

[2] Trueman, "The Lias of South Lincolnshire": Geol. Mag., 1918, p. 108.

attenuated near the anticlinal axes, and would be best developed in the synclinal areas.

The variations in the thicknesses of these zones will now be considered in order to see whether there exists any definite relationship between such variations and the positions of the postulate folds.

(1) *Acutum Zone.*—The *acutum* zone is especially suitable for the present purpose for several reasons. As the "Transition Bed" between the Middle and Upper Lias, and containing many fossils, it has received much attention. It has also been well exposed in many workings for Marlstone Ironstone, while it is very thin and its fossils easily recognized, so that there are few records that cannot be utilized.

The distribution of the deposits of *acuti* age constitutes a striking confirmation of the suggested folding.[1] While the *acutum* zone is well represented around Lincoln, it is probably absent at Grantham, appearing again as a thin layer at White Lodge near Waltham-on-the-Wolds, Leicestershire, in the Old Dalby syncline. In the neighbourhood of the Melton Mowbray anticline the *acutum* zone has not been recorded, a fact which makes it extremely probable that the zone is not represented there. South of this region, however, in the Tilton syncline, the zone attains its best development around Tilton. It has again not been recorded anywhere in the neighbourhood of the postulated Market Harborough anticline, and it is likewise thin or absent along the line of the supposed Weedon anticline, but its presence has been proved in the intervening district, which includes what we propose for convenience to refer to as the Cold Ashby syncline.

Again, between Northampton and Banbury the *acutum* zone is well seen, and has been described by many observers at Chipping Warden and Byfield. Towards the suggested anticline through Banbury, however, the deposits again thin out, and at King's Sutton a very attenuated representative rests on an eroded surface of Marlstone. West of this line the *acutum* zone once more thickens in the region of the Edgehill syncline, but still further south or west it has not been found.

At several localities, such as Aston le Wall and Milton, situated near the lines of the postulated anticlines, the deposits contain rolled materials or pebbles, a further evidence of slight erosion.

(2) *The Tenuicostatum Zone.*—The *tenuicostatum* zone (formerly miscalled the *annulatum* zone) occurs at the base of the Upper Lias immediately above the Transition Bed (*acutum* zone). In many

[1] The thicknesses of zones have been obtained mainly from the following sources: Judd, *The Geology of Rutland, etc.* (Mem. Geol. Surv.), 1875. Walford, Proc. Warwick. Nat. Field Club, 1878, p. 37. Thompson, Journal Northants Nat. Hist. Soc., vol. ii, 1882–3. Wilson & Crick, Geol. Mag., 1889, p. 296. Thompson and others in Report of Brit. Assoc., 1891, pp. 334–51. Woodward, *Lias of England and Wales* (Mem. Geol. Surv.), 1893. Richardson, *Handbook to the Geology of Cheltenham, etc.*, 1904. Truen an, Geol. Mag., 1918, pp. 106–8.

records no attempt has been made by authors to identify the Dactyliocerates of this zone, but as the deposits are frequently paper shales, and constitute the lower part of the "Fish Beds", or Dumbleton Beds of Professor Judd,[1] it can generally be identified from descriptions of the sections.[2]

It has been shown by Mr. Buckman and others that the *tenuicostatum* zone attains its maximum thickness in Yorkshire, is thick in Lincolnshire, and thence southwards is recognizable as a very thin layer.[3] But this generalization is upset by a sudden thickening of these beds along the Bredon syncline, for at Dumbleton they are extremely well developed, a fact which further suggests the existence of a basin there in Liassic times.

As the *tenuicostatum* zone is traced southwards from Lincolnshire, in those districts where a sufficient number of thicknesses is available, further indications are obtained of intra-Liassic movement; this again appears to have occurred along the axes that have been previously noticed. There is, for instance, a slight thickening in the Old Dalby syncline, although the zone generally is rapidly thinning out southwards. The probable absence of the zone in the district around Weedon near the Weedon anticline is interesting, as the zone is certainly present at Chipping Warden and further to the south-west. The zone once more thins towards Banbury, and Mr. J. Pringle informs us that he believes it to be absent just north-west of Banbury, where the overlying *exaratum* zone, itself attenuated, rests with a non-sequence on an inconstant representative of the *acutum* zone which fills small hollows in the underlying Marlstone. There was, therefore, but little deposition over this region during a period in which deposits belonging to several zones were accumulating elsewhere. Still further south-west, paper-shales occur at Chipping Norton in the Edgehill syncline, but thin out once more towards the line of the Moreton anticline, only to thicken in the Bredon syncline, as we have already indicated.

The results obtained from our study of the *acutum* and *tenuicostatum* zones are summarized in the table on p. 203, in which it is seen that the variations in these two zones take place at exactly those localities where they would be expected if the folding which is indicated by the course of the outcrops was in progress during the periods of deposition. In each case the deposits thicken towards the synclines and thin away towards the anticline.

(3) *Other Zonal Evidence.*—While it is not yet possible to follow other zones in similar detail across the whole of the Midlands, there are certain zones traceable for short distances which afford further evidence of some of the supposed intra-Liassic movements.

[1] Judd, *The Geology of Rutland, etc.* (Mem. Geol. Surv.), 1875, p. 83, etc.

[2] Although in some of our figures, perhaps a portion of the *exaratum* zone may also be included.

[3] Buckman, "Certain Jurassic (Lias-Oolite) Strata of South Dorset, etc.": Quart. Journ. Geol. Soc., vol. lxvi, 1910, p. 88.

Suggested folds.		Old Dalby Syncline.	Melton Mowbray Anticline.	Tilton Syncline.	Market Harborough Anticline.	Cold Ashby Syncline.	Weedon Anticline.	Badby Syncline.	Banbury Anticline.	Edgehill Syncline.	Moreton Anticline.	Chipping Campden syncline.	Winchcombe Anticline.	Bredon Syncline.
acutum zone	? Absent	*	? Absent	*	? Absent	*	Thin	*	Absent	*	Absent			
tenuicostatum zone	*	Thicker	?	*	*	*	? Absent or thin	*	Absent or Thin	*	Thin	*	Thin	Thick

* Denotes zone present.

For instance, the *planorbis* zone in the Old Dalby syncline shows a characteristic thickening from Owthorpe and Cotgrave Gorse on the north to East Leake, near the synclinal axis.[1] Further south again, at Barrow-on-Soar, the zone is again thinner. These facts are extremely suggestive of movement along the axis in Lower Liassic times, but unfortunately no details of this zone are available further south.

The chief lack of information concerning many zones is due to the broad way in which they have been interpreted. Minute zonal studies on the lines indicated by Mr. Buckman's recent work[2] cannot fail to yield a great deal of useful information, for in many cases the zones he defines are so thin and have a fauna so distinct that given sufficient exposures it will be a comparatively easy matter to trace their extent.

Meanwhile it has only been possible to collect isolated facts, but some of these are significant. For example, the capricorns of the *Liparoceras* series, which mark a definite but comparatively short period of time, have only been found at Dumbleton and Napton-on-the-Hill, Warwickshire, both of which are situated on supposed synclinal lines.[3]

(4) *Other Types of Evidence.*—Working on the same principle, attempts were made to trace any relationship between the folds and the thicknesses of the strata, using the total thickness of whole formations. The attempts were unsuccessful, partly on account of the few data available, there being a surprising lack of records that give, for instance, the total thickness of the Lower or Upper Lias; further, the small variations that may be expected as a result of any contemporaneous folding are superposed on large-scale regional variations due to regional tilting, or to secular elevation which was in progress at the time of deposition. For instance, during Toarcian (Upper Lias) times the area of maximum deposit moved southwards

[1] Trueman, Geol. Mag., 1918, pp. 67–70.

[2] Buckman, "Jurassic Chronology: I. Lias": Quart. Journ. Geol. Soc., vol. lxxiv, 1919.

[3] Trueman, "The Evolution of the Liparoceratidæ": Quart. Journ. Geol. Soc., vol. lxxiv, 1919, p. 252, etc.

from Yorkshire as a consequence of some regional movement; the results of the regional movement almost completely conceal the results of any minor flexuring during that time. Attention has in the past naturally been drawn to the larger lateral variations, with the result that any minor or local variations superposed on the regional ones have been overlooked.

As remarked above, we have failed to accumulate sufficient evidence to prove the occurrence of such local variations in the formations considered as a whole. But so far as the records go, they tend to confirm the results obtained by a critical examination of subdivided zones, such as the *acutum* and *tenuicostatum* zones detailed above. For example, the collected figures suffice to show that the Upper Lias thickens in the Old Dalby syncline and in the Bredon syncline. As regards the Lower Lias, there are evidences of local thickening in the synclinal areas of Bredon and Badby. As regards the Rhætic there is again a thickening in the Bredon syncline, and perhaps also in the Old Dalby syncline. It seems probable, therefore, that when sufficient data are available concerning thicknesses of other zones and subdivisions, it will be possible to trace the effects of the local movements in most of the divisions between the Rhætic and the Inferior Oolite. In this way it may prove possible to separate the effects of local uplifts from those due to regional movements involving widespread tilting with consequent transgression or regression.

(5) *Evidence of Movements from post-Bathonian Rocks.* We have shown above that an examination of certain thin zonal deposits appears to confirm the evidence of outcrop that folding was in progress at intervals in Liassic time. Variations in thicknesses of the major divisions yield some additional support. Taken in conjunction with the results already mentioned as obtained by Mr. Richardson, that local movements were taking place in Rhætic times along the same lines that were afterwards followed by Bajocian movements, we find that there was gentler but almost continuous movement along definite lines up to about the end of Bajocian time. Then these particular movements appear to have ceased, for the outcrops of the Bathonian and higher formations are but little affected.

Nevertheless, it is still possible to trace the southward prolongation of the folds beyond the area occupied by Bajocian rocks, because movement along the same lines seems to have been renewed at certain later periods, so that along the anticlinal lines denudation was repeatedly at a maximum. Thus it is more than a coincidence that along the southward prolongation of the Moreton anticlinal axis the Lower Cretaceous Sands should at Faringdon suddenly come to rest directly on the Corallian, while still further south, just where the prolongation of the same line crosses the Vale of Pewsey uplift, the Tertiary beds overstep nearly the whole of the Chalk and come into their closest proximity to the Upper Greensand.

Similarly at Wallingford on the southward prolongation of the Banbury axis, the course of the Upper Greensand outcrop clearly indicates the existence of gentle anticlinal folding.

In the region further east, Mr. R. H. Rastall has called attention to the anticlinal disposition of the Upper Jurassic with regard to an axis of maximum erosion which passes north-westwards through Sandy (10 miles east of Bedford), and he has explained the structures as due to a pre-Cretaceous posthumous uplift of the Charnian axis.[1]

IV. Relation of the Folds to Palæozoic Outcrops.

It is only to be expected that several of these axes of Mesozoic uplift should be aligned with uplifts that have resulted in exposing the nearest outcrops of Palæozoic rocks. Thus the Moreton and Winchcombe anticlines are aligned respectively with the Warwickshire and South Staffordshire Coalfields, and the Chipping Campden and Bredon synclines with the troughs between the Warwickshire and South Staffordshire and South Staffordshire and Forest of Wyre Coalfields, while the connexion between the Melton Mowbray anticline and the uplift of pre-Cambrian rocks in Charnwood Forest has been discussed elsewhere.[2] The connexions between the remaining anticlines, the Banbury, Weedon, and Market Harborough folds and the nearest Palæozoic rocks are not so clear, but it will be shown that there are reasons for connecting both the Banbury and the Weedon folds with the Warwickshire Coalfield, and the Market Harborough fold with the Charnwood Forest area.

Several of these areas of Jurassic folding have already been explained as due to posthumous movements along axes of Palæozoic uplift. This was suggested as early as 1901 by Mr. Buckman, in discussing the Bajocian rocks of the North Cotteswolds;[3] Mr. Buckman showed that penecontemporaneous "erosion is likely to have taken place along similar lines at different times, and therefore may be connected with the folds in the Palæozoic rocks, and may have a bearing on the thickness of the rocks overlying the coal measures".[4] Professor W. S. Boulton has more recently suggested that minute Jurassic zonal studies will all have their value when estimating the nature and thickness of cover over the buried coal measures.[5] A similar suggestion was made by Professor P. F. Kendall regarding anticlinal axes in East Anglia,[6] by Mr. Rastall[7] for the pre-Cretaceous uplift which caused excessive denudation of Upper Jurassic rocks along a continuation of the

[1] Rastall, *Cambridgeshire*: Geology in the Field, pt. i, 1910, p. 143.
[2] Cox, Phil. Trans., ser. A, vol. 219, Appendix, 1919.
[3] Buckman, "The Bajocian of the North Cotteswolds": Quart. Journ. Geol. Soc., vol. lvii, 1901, pp. 147–9.
[4] Op. cit., p. 154.
[5] Presidential Address to Section C (Geology), Report Brit. Assoc., Newcastle-on-Tyne, 1916, p. 383.
[6] Report of the Royal Commission on Coal Supplies, pt. ix, Appendix iii.
[7] *Cambridgeshire*: Geology in the Field, pt. i, 1910, p. 143.

Charnian axis, and again by one of us in the recently recognized Melton Mowbray uplift.[1]

It will be noticed that the axial lines of the flexures change in direction from east-west at Melton Mowbray to north-west—south-east at Market Harborough, then to approximately north-north-west—south-south-east at Daventry and at Banbury, and finally to a north-south direction in the two cases of the Vale of Moreton and the Winchcombe structures. The variation in the direction of the different axes may be ascribed to splitting and fingering-out southwards of the main axis of post-Triassic uplift, the Pennine axis. The fingering-out of the post-Carboniferous pre-Permian Pennine uplift has been described by Professor Kendall[2] and by Professor Fearnsides,[3] and it was ascribed by the latter writer to a lagging of the eastward-moving folds as they approach the buried area of older rocks which we know to underlie East Anglia. If, as the structures indicate, the Triassic and Jurassic movements followed the lines of the earlier pre-Permian movement, the radial arrangement of the fold-axes is readily explained. The existence of such a radial arrangement serves to account for the increased number of anticlinal areas in the south and east as compared with the central Midlands. If it were possible to differentiate and map particular horizons in the thick Keuper Series, as has been accomplished by Dr. Matley[4] over part of Warwickshire, it would probably prove easy to trace all the folds from the Jurassic rocks across the intervening Keuper to the Palæozoic areas, and so to see the southward splitting of certain of the fold-axes.

Further, it should be noted that, while the Nottinghamshire, Warwickshire, and South Staffordshire Coalfields all have a north-south alignment, due to post-Triassic movements which have affected the Mesozoic cover, the Palæozoic rocks in each coalfield show the presence of other axes due to older north-westerly movements oblique to the present alignment. For example, the Warwickshire Coalfield has two marked Charnian anticlinal axes, each of which brings up Cambrian rocks. One of these axes is on the present north-eastern margin of the coalfield at Nuneaton and the other on the western margin at Dosthill,[5] so that the structure within the coalfield is complex, due to two systems of uplifts which cross one another obliquely, one pre-Triassic and one post-Triassic. Now in each case it is probable that while the north-south post-Triassic movements were in progress, there was simultaneous posthumous

[1] Cox, Phil. Trans., ser. A, vol. 219, Appendix, 1919, p. 124.

[2] Report of the Royal Commission on Coal Supplies, pt. ix, Appendix iii, 1905.

[3] "Some Effects of Earth-movement on the Coal Measures of the Sheffield District," Part II: Trans. Inst. Min. Eng., vol. li, pt. iii, 1916, p. 107 (with references).

[4] Matley, "The Upper Keuper (or Arden) Sandstone Group and Associated Rocks of Warwickshire": Quart. Journ. Geol. Soc., vol. lxviii, 1912, p. 269.

[5] *Geology of the Country around Lichfield* (Mem. Geol. Surv.), 1919, p. 7.

movement along the older Charnian axes.[1] If this were so it would explain why more than one of the Jurassic anticlines connects with the present visible Warwickshire Coalfield.

If now we are justified in our conclusions that each of these slight uplifts in the Mesozoic rocks of the Midlands indicates the line of a deeper-seated and more powerful uplift in the underlying Palæozoic rocks, the importance of their further study is obvious, and it is seen that detailed zoning and detailed records of thickness may prove of import for the tracing of the larger underground structures. Any facts which may shed light on the underground structure of this region are doubly valuable because of the possibility of the existence of concealed coalfields. Taken in conjunction with the gradually accumulating evidence as to the depth of the Palæozoic floor,[2] the Mesozoic folds may yet serve as guides to the most likely areas for finding productive coal-measures at reasonable depths.

V. General Consideration of the Underground Structure of the Southern Midlands.

Surveying the underground structure of the country as a whole, attention may be called to a peculiar symmetry in the general deposition of the Palæozoic rocks. In the centre of England we have the Pennine axis which fingers out southwards into a number of subordinate folds in Carboniferous rocks. They are flanked to the south-east by a large area of older rocks, Devonian and Silurian with some Cambrian and pre-Cambrian, which underlies, so far as we know at present, most of the district between Northamptonshire, Buckinghamshire, Herefordshire, and East Anglia.[3] This mass of older rocks occupies much the same position on the south-east side of the Pennine axis as the mass of Devonian, Silurian, and older rocks in Wales, on its south-west side. Not only so, but just as the Welsh rocks have a predominant south-westerly strike which gradually swings to east and west in South Wales, so the East Anglian mass, judging from present information, is affected by south-easterly structures which probably swing round to east-west under the region of the Thames estuary. The Kent Coalfield, with its highly inclined Carboniferous rocks, may thus compare structurally with the Pembrokeshire Coalfield, with its highly compressed structures. In each case the compression of the Carboniferous rocks may be accounted for by proximity to an area in which the Lower Palæozoic rocks strike east and west.

[1] Compare Matley, op. supra cit.; also A. Morley Davies & J. Pringle, "Two Deep Borings at Calvert . . .": Quart. Journ. Geol. Soc., vol. lxix, 1913, p. 335; also Baker, "Charnian Movement in East Kent": Geol. Mag., Dec. VI, Vol. IV, 1917, p. 398.

[2] Strahan, Presidential Address: Quart. Journ. Geol. Soc., vol. lxix, 1913, p. lxx. See also A. Morley Davies & J. Pringle, ibid., p. 334.

[3] Strahan, op. cit.

Various further coincidences in symmetry appear, such as disposition of the pre-Cambrian and Cambrian rocks of Leicestershire, with their south-easterly strike as compared to the pre-Cambrian and Cambrian rocks of Shropshire, with their south-westerly strike. Yet other resemblances become apparent from a study of the map, and it seems likely that a fuller knowledge of the distribution of the concealed Palæozoic rocks would yield yet other similarities.

VI. Summary.

1. The occurrence of anticlinal folding during Jurassic times has been demonstrated by Mr. Buckman's detailed zonal work in the Vale of Moreton and in the North Cotteswolds. These anticlines are indicated on the map by marked bends in the outcrops of the Lower Jurassic formations.

2. Similar bendings of outcrops are seen at several localities in the Eastern and Southern Midlands, and the structure at one such locality—Melton Mowbray—has recently proved to be anticlinal.

3. Intra-Jurassic folding betrays itself by non-sequences and reduced thicknesses of Lower Jurassic zones along anticlinal axes. Such evidence suggests the existence of anticlinal structures in the neighbourhood of Banbury, Weedon, and perhaps also Market Harborough, in addition to the cases mentioned above.

4. Movement was probably almost continuous along some or all of these axes, at least from Rhætic to Bajocian times. Outcrops of post-Bathonian formations are not affected by the flexures, although the folding was perhaps renewed in later Jurassic or even Tertiary times.

5. Several of these lines of Jurassic folding probably follow the lines of earlier and more powerful movements. The bearing of such flexures on the structure of the Palæozoic floor is discussed.

6. Attention is called to a curious symmetry in the disposition of the Palæozoic formations on either side of a prolongation of the Pennine axis.

Note on a New Vole and other Remains from the Ghar Dalam Cavern, Malta.

By Dorothea M. A. Bate, Hon. M.B.O.U., F.Z.S.

In 1916[1] the writer published a list of the vertebrates of which remains had been obtained from the Pleistocene cave and fissure deposits of Malta. Early this year (1919) a few rather fragmentary remains were forwarded by Mr. G. Despott to the British Museum (Nat. Hist.) for identification. These are from the Ghar Dalam Cavern, from which a number of specimens have already been obtained.[2] As some of the specimens lately received add to

[1] Proc. Zool. Soc., 1916, p. 421.

[2] Proc. Roy. Soc., vol. liv, 1894, p. 274.

our knowledge of the fauna in question, it may be worth while to record the following notes.

Mammalia.

Mammalia are represented by fragmentary remains of *Cervus elaphus*, var. *barbarus*, of two species of rodents and of a small fox. Included among the rodent remains is a right femur of an immature animal, and this appears to agree most closely with that of *Rattus*, which has not been recorded previously from the cave deposits, but two species of which, *R. decumanus* and *R. alexandrinus*, are recorded in Dr. Gulia's list of the recent mammals of the Maltese Islands.[1]

Another species is represented by a left and right mandibular ramus, the former containing the incisor only, while the latter still retains the two anterior cheek teeth as well as the incisor. There are also two right femora and a tibia, which seem to belong to the same species. The mandibular rami have been compared with those of several species both recent and extinct, and so far as can be judged from such scanty material they appear to represent an undescribed species most nearly allied to *Arvicola* (*Tyrrhenicola*) *henseli* Major, from the Pleistocene ossiferous breccias of Sardinia.[2] It is proposed that the Maltese species be known as—

Arvicola melitensis, sp.n.

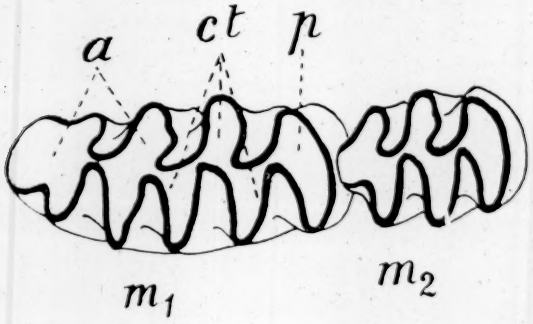
The characters of the lower jaw and teeth show it to be closely allied to *A.* (*T.*) *henseli*, from which it may be readily distinguished by its considerably smaller size. Owing to the imperfect state of the specimens it is difficult to give comparative measurements other than the antero-posterior length of the first two cheek teeth, which in *A. henseli* is 5·5 mm. and in *A. melitensis* 4·5 mm. Although possibly not a constant character, it may be worth mentioning that in Dr. Forsyth Major's figure[3] of the crown-pattern of the lower dentition of *A. henseli* the whole of the dentine area of the anterior loop is confluent, whereas this loop in *A. melitensis* is practically divided into two parts (see Text-figure).

As in *A. henseli* the lower cheek teeth in *A. melitensis* are rather wide crowned, and the enamel is somewhat thinner than in the recent *Pitymys*. Dr. Forsyth Major's subgenus, *Tyrrhenicola*, was based chiefly on cranial characters, and it will be interesting to see if further material from Malta bears out the close relationship indicated by the lower jaw.

Other mammalian remains consist of the anterior half of a left lower carnassial, a left lower canine, and a number of imperfect limb bones of a small species of *Vulpes*. These, as also some specimens belonging to the Manchester Museum kindly lent by Mr. J. Wilfrid Jackson, have been carefully compared with many

[1] Ninth International Zool. Congress, Monaco, 1913, pp. 545–55.
[2] Geol. Mag., 1905, p. 504.
[3] Loc. cit., p. 505.

recent and fossil species in the British Museum. They seem to show no characters sufficiently constant or distinctive to warrant their separation as a distinct species, but evidently represent a small race with a weak dentition and slender limbs, smaller than *V. ichnusæ* from Sardinia, and probably approximating in size to *V. nilotica*, of which no skeleton has been available for comparison. The extreme slenderness of the proximal articulating surfaces of two metatarsals from Malta is very noticeable. Much variation in size is indicated by the Maltese specimens.



Arvicola melitensis, sp. nov. Crown view of first and second right lower molars. Enlarged × 15 diam. *a*. anterior loop; *c.t.* closed triangles; *p*. posterior transverse loop.

There is in the British Museum the distal end of a humerus (M. 8159) from the Pleistocene of Corsica, which seems to agree closely in size with the Maltese form. No fox is found living in Malta at the present day, the only land carnivores being *Mustela nivalis boccamela* and *M. africana*, the latter possibly introduced through human agency.[1]

Reptilia.

Reptiles are represented by a few fragments of carapace, ascribed to *Lutremys europæa*, and by several limb bones, pelvic bones, two vertebræ, and the base of a skull of *Bufo vulgaris*, Laur. These latter specimens have been kindly examined by Dr. G. A. Boulenger, F.R.S., who considers that from the characters of the sacral vertebra they may be confidently assigned to this species. Previously no specifically identified remains have been recorded; Leith Adams in his "List"[2] mentioned only "Batrachia sp. Frogs or Toads, sp."

It is interesting to note that apparently no toad occurs in the Maltese Islands at the present day, the only batrachian being *Discoglossus pictus* Otth.[3]

[1] See Miller, *Cat. Mamm. West. Europe*, 1912, p. 414.
[2] Quart. Journ. Geol. Soc., vol. xxxiii, 1877, p. 177.
[3] See Dr. Gulia, loc. cit.

AVES.

Bird remains are represented by only a few imperfect bones, but these are worth mentioning, some being those of passerines; one the proximal portion of a right humerus of *Turdus ? musicus*. So far as I am aware remains of passerine birds have not been previously obtained from Maltese deposits.

My best thanks are due to Dr. Smith Woodward, F.R.S., for allowing me to examine this interesting little collection, and to Mr. M. A. C. Hinton for valued help in their determination.

Notes on Lateritization in Sierra Leone.

By F. DIXEY, M.Sc., F.G.S., Government Geologist, Sierra Leone.

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(PLATE III.)

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I. INTRODUCTION.

IN the course of the Geological Survey of Sierra Leone in 1918–1919 certain features of interest were observed in the lateritization of the norite [1] of the Colony and of the Pleistocene deposits which form the coastal plain surrounding the norite mass. These features form the basis of the following notes.

Laterite is a rock of variable composition, consisting of a mixture of hydrated oxides of iron, aluminium, titanium, and, rarely, manganese, and formed by the superficial decomposition of certain rocks; it is a residual accumulation resulting from the removal in solution from the rocks affected of combined silica, lime, magnesia, soda, and potash. It may be formed by the alteration in situ of original rocks or by the alteration of detrital deposits; the first of these two products is termed high-level or residual laterite, and the second, low-level or detrital laterite, or, as suggested by Dr. L. L. Fermor, "lateritite." [2]. The detrital laterite is made up of the detritus of other forms of laterite, mixed with the quartzose and argillaceous detritus of granitic and other rocks; the whole is cemented together by the action of water on the lateritic constituents.

[1] The present author hopes to publish an account of this norite at an early date.

[2] Fermor, "What is Laterite?": GEOL. MAG., 1911, p. 507.

2. (i) Lateritization of the Norite. (Pl. III, Fig. 1.)

The country rock of the Colony is a medium-grained norite, associated with which is a relatively small development of a coarse norite and an aplitic variety; the medium-grained type offers the best means of following the process of lateritization.

In consequence of rapid erosion induced by high relief, laterite formed in situ has been unable to accumulate to any considerable depth except in special circumstances. On valley-sides, hill-crests, and cols, the laterite is rarely more than a few inches deep. On rounded hills and gentle slopes the country rock crops out in a characteristic manner as numerous large boulders and crags, or even low isolated rounded surfaces. The outstanding character of these various masses is due in all cases to lateritization, which progressed along master joints. The lateritized portion was more readily removed by erosive agencies, and the masses of unaltered rock were left standing in relief. The masses of rock exposed in this way exfoliate in thin shells and gradually assume a rounded form. Their exposed surfaces are either fresh or covered with only a thin skin of laterite. Where the rock is closely jointed, lateritization proceeds uniformly throughout and extends to a depth of several yards. Examples of this occur over part of the gentle slope[1] on which the W.A.R. camp stands, near Wilberforce, and in the valley of the Congo south-west of Freetown. The depth of lateritization was so great on the right bank of the Congo at a height of about 500 feet O.D. that a project for building a small dam across the valley ended in failure, because it would have been necessary for the dam to rest everywhere upon solid rock, and the cost of this was prohibitive.

A clearing was made up the steep valley sides just above a narrow gorge; on the left bank the norite was exposed under a thin cover of laterite, but on the right an excavation cut through 12 feet of laterite before exposing the norite, and even when extended laterally met only the altered rock. The alteration had proceeded along joints until only cores of unaltered rock were left; the cores were in the form of slabs because of the platy jointing prevailing in this place. The slabs or cores were surrounded by more or less concentric layers of red laterite, which became more irregular in shape outwards. Sometimes all that remained of the original mass was a red "ghost" with concentric lamination and an irregular outline.

In most localities in the Colony the core of a lateritized mass tends to become continually more rounded in form as it diminishes in size. But where the norite is banded lateritization sometimes

[1] Cf. Professor Lacroix, "The formation of a continuous crust depends on definite topographical conditions (horizontal plateau or gentle slope of ground)." Fermor, "The Work of Professor Lacroix on the Laterites of French Guinea": Geol. Mag., 1915.

proceeds rapidly along certain bands, which when dipping at a high angle are altered to a considerable depth. A number of little coves and a series of parallel reefs running out obliquely from the shore owe their origin to the removal of such weathered bands by wave action. Examples can be seen about Kent and near Aberdeen Creek.

It is possible to trace in the hand specimen the change from a core of unaltered norite to the outer zone of red-brown laterite ("gibbsitic laterite" of Professor Lacroix[1]). The grey core is enclosed by a pale cream-coloured halo with brown pseudomorphs of the pyroxenes. This pale halo gives place gradually through yellow and then brown to the red-brown outer zone; the halo and the outer zone correspond respectively to Professor Lacroix's "zone of leaching" and "zone of concretion".[2] The transition from core to halo is a rapid one and takes place within 0·2 in. The colours of the halo and succeeding zones are due to a whitish alteration-product of the felspars, which becomes stained to an increasing depth as the ferromagnesian minerals decompose. As the alteration progresses the individual crystals gradually become unrecognizable and the mass itself becomes crowded with small concretions and pierced by narrow ferruginous veins, until finally it forms coarsely porous red laterite. This secondary laterite bears close resemblance to that formed from detrital deposits.[3]

As regards individual minerals *felspar* is the first to be affected. It passes into a white opaque alteration product, which spreads along the cleavage cracks, and for a time leaves flakes of the mineral fresh and unaltered. Then a clear white recrystallization sets up along the old cleavage cracks and the remaining parts of the crystal dissolve out, resulting in a framework of parallel plates studded with minute colourless crystals (probably gibbsite). Later iron staining commences, and the pseudomorph gradually breaks up. *Diallage* changes in colour from almost black to brown at a very early stage, and with the rhombic pyroxene causes a mottling of the light-coloured halo; it is then gradually pseudomorphed in parallel brown scales, exceedingly fine, and possessing an earthy lustre. The *rhombic pyroxene* develops a close, platy structure, and retains its bronzy lustre to a late stage. The *iron-ore* is recognizable, and apparently unaltered long after all the other minerals have disappeared. *Olivine* is not recognizable after lateritization has commenced.

[1] Op. cit., p. 35.

[2] Op. cit., p. 34.

[3] Cf. Arsandaux: "Toutes les formations latéritiques montrent deux zones: (i) La première zone, contiguë à la roche originelle en reproduit exactement la structure; elle en constitue une véritable pseudomorphose; les felspaths de la roche fraîche sont remplacés par une matière blanche; les éléments colorés par du sesquioxyde de fer. (ii) La seconde zone, superposée à la première, est dépourvue de tout ordonnancement de ses éléments constitutifs" (*Handbuch der regionalen Geologie*, vii, 6*a*, p. 61).

(ii) Alteration of Norite rich in Iron.

Lateritization proceeds very readily where the norite is rich in disseminated magnetite (titanomagnetite), but it goes on slowly if the proportion of iron be increased beyond a certain point. This is illustrated on the foreshore west of Aberdeen Creek, where certain inclined bands in the norite have been thoroughly lateritized for many yards along their outcrop, and seams of magnetite in them, up to 2 inches thick, run practically unaltered from norite into laterite. Some of the seams contain a little felspar in parallel arrangement with the magnetite. In such cases the magnetite is often left as a spongy mass on the weathering of the felspar. Further within the lateritic masses there occur more or less spherical cores of iron-rich norite, enclosed in concentric shells; such cores apparently owe their unaltered state to a high iron content.

In addition to the seams of magnetite in the normal norite, there occur locally in the coarse norite irregular crystals and small spongy masses of magnetite which also remain unaltered when the enclosing rock is lateritized. Good examples of these masses, and of crystals ranging up to 3 inches in length, can be seen in coarse norite exposed on the foreshore immediately south of York.

3. Lateritization of Granitic Rocks.

The solid rocks of the Protectorate have been lateritized to a considerable depth in many places. Where they rise above the Pleistocene deposits of the plain they are frequently seen in railway and road cuttings to be lateritized to a depth of 15 feet, and sometimes to 20 or even 30 feet (Pl. III, Fig. 2). In the more hilly and mountainous parts of the country, especially in the north, laterite is not nearly so well developed. The mountain sides are often very steep and bare, and uncovered by vegetation except for a few tufts of grass, and even in the broad valleys opening out on to the plain, and on the northern part of the plain itself, the laterite occurs only as patches of gravel. The conditions in this part of the country are similar in many respects to those of the mountain districts of Mozambique, concerning which Dr. A. Holmes states:[1] "It is important to notice that the steep slopes of the inselberg peaks and mountain blocks are always free from deposits of the lateritic constituents. Solutions must certainly exist which on evaporation would give rise to such deposits, but the mountain rains and night dews suffice to carry them down to the debris-covered plateau surface below, where they contribute to the formation of the lateritic earths which so frequently sweep around the base of the hills."

The lateritization of the granitic rocks proceeds as follows: the rocks become broken down into small masses by weathering at the surface and by decomposition along joints and the less resistant bands; the decomposition then proceeds inwards from the outer

[1] "The Lateritic Deposits of Mozambique": Geol. Mag., 1914, p. 534.

surface of each mass and forms generally a white kaolinized shell, which continually increases in thickness until it involves the whole mass. The white mass gradually breaks up later and becomes increasingly stained on the destruction of the iron-ores and ferromagnesian minerals: it forms finally a great thickness of soft red-brown lateritic clay, almost homogeneous in composition and texture. The uppermost portion of this lateritic clay then forms locally a hard crust of laterite up to several feet in thickness, due to the growth and ultimate coalescence of numerous small ferruginous concretions which gradually appear in it. In some places the concretions give rise only to a coarse laterite gravel.

A similar decomposition of the mica-schists, gneisses, and granites of French Guinea has been described by Professor Lacroix.[1] He includes the kaolinitic decomposition product and the lateritic clay in his "zone of leaching" and the laterite crust in his "zone of concretion". The granites of Mozambique,[2] however, are rarely kaolinized; where they have undergone this mode of alteration, the kaolin does not pass into lateritic clay and laterite, but is capped by a thickness of damp, black soil. The alteration in this case is ascribed to a heavy growth of vegetation.

It can frequently be demonstrated in railway cuttings (Pl. III, Fig. 2) that a great thickness of laterite may be formed from alteration in situ of crystalline rocks, for the forms of the original masses are still in evidence, and so also are the quartz veins which pierced them; such masses are now represented only by faint patches or ghosts, whereas the quartz veins stand out clear and unaltered, showing their original form and foliation. There is a progressive change from the unaltered rock to the laterite crust, the crystalline rocks in this way presenting a marked contrast to the basic rocks (p. 212).

The Pleistocene and Recent beds of the plain become lateritized in a similar manner, and the resultant product is indistinguishable from the laterite formed directly from the crystalline rocks.

Lateritic iron-ores are formed locally where iron is abundant in the country rock, but with the exception of those in the Colony (as distinct from the Protectorate) (see p. 217), they are of no importance.

4. (i) Lateritization of Detrital Deposits.

Detrital deposits are also affected by lateritization changes. The phenomena are apparent in a series of stratified beds, which cover the marine platform encircling the Colony. Other detrital deposits affected are the surface accumulations in valleys and gaps, and talus-slopes resting on the steep seaward flanks of the hills. Phenomena similar to those described below are well exposed along the cliffs of the Bullom Shore and in cuttings along that part

[1] Op. cit., pp. 36, 80.
[2] Holmes, op. cit., p. 536.

of the railway running between Waterloo and Songo. The deposits of the Bullom Shore range from coarse felspathic sands to almost pure clays. Lateritization is most pronounced in the sands and diminishes in the more argillaceous beds until it is practically non-existent in pure clay. The probable explanation is that the sands allow surface waters to percolate through them more freely, and also that they contain a much higher proportion of iron in the form of grains of magnetite.

The typical laterite exposed along the cliffs and in stream beds is a red-brown to bright red scoriaceous rock, moderately hard, and in the hand specimen coarsely porous; the diameter of the pores is about 0·4 in. The texture of the walls surrounding the pores is usually compact, the surfaces being smooth or rough according to increasing size and number of the sand grains. The laterite locally contains small masses, lenticles, and streaks, rarely exceeding 2 feet in length, of loosely compacted yellow sand, mixtures of sand and magnetite grains cemented into a purple mass, and of clay containing anything from mere iron staining to a very high proportion of hæmatite and limonite. When a small lump of the laterite is exposed to the weather for a long time it acquires a smooth lustrous surface, dark-brown to black in colour. The pores in the laterite often remain of uniform character to a depth of many yards; beyond this depth the porous mass passes into a red compact sand pierced by irregular streaks and pipes cemented by iron oxides.

This porous laterite forms a hard crust about 10 feet thick at the top of the Pleistocene deposits of the platform; it is exposed along the upper part of the cliffs and as huge fallen blocks at their foot.

Origin of the Scoriaceous Laterite.—Lateritization depends largely upon the amount of iron originally contained in the beds subject to the alteration, and also upon the ease with which water can percolate through them. Just as the modern marine sands vary considerably in their degree of fineness and the proportion of iron and silt they contain, so probably did the older deposits now upraised to form the Pleistocene platform.

The sandy deposits offer the best means of observing the changes involved, which were as follows:—

Owing to the breaking down and hydration of the iron by the combined effects of waters and varying temperatures, pale yellow spots were produced in the beds. The material forming the spots hardened into little lumps about the size of a pea; as these lumps grew larger their centres became brown, and then red, possibly as the result of increasing dehydration. Consequently, at any later stage, they possessed concentric colour-zones in red, brown, and yellow. In time the lumps, or concretions, coalesced into irregular nodular masses. These masses finally formed a thick crust and arrested the concretionary processes by causing the waters to flow in definite channels through or over the surface of the crust, instead of

percolating through the centre mass. If at this stage the rocks are exposed to the action of erosive agencies, the unaltered sands between the concretions are washed out, and only a coarse red mass remains; this mass tends to become harder and more porous as time goes on. This process is illustrated at any place where cliffs formed of Pleistocene deposits are being eroded by the sea, for the waves continue to cut out the soft sandy beds under the crust until it falls to the foot of the cliffs in large yellow-brown masses. When newly fallen these masses are rubbly and easily broken; soon, however, they commence to harden and the soft material between the concretions is worn away, leaving only the red, porous laterite. When the iron is distributed locally and irregularly it forms ferruginous strings and pipes traversing a mass of partially compacted sand.

In the sandy clays the changes take place more slowly, and the growing ferruginous concretions do not harden until a much later stage in the general alteration is reached. Meantime, the partly altered beds remain uncemented and brightly mottled in purple, red, brown, and yellow. As compared with laterites formed from less clayey beds the concretions in the sandy clay are smaller and the resulting mass less coarsely porous.

The thick beds of white, cream, or grey clays do not alter appreciably, except to acquire irregular films of hæmatite due to the infilling of desiccation cracks. The red and yellow or red and white mottled clays which collect locally in passes and in valleys owe their colouring to the above processes; they do not contain enough iron to produce hard concretions, and consequently they remain plastic while wet, and become hard and compact when dry.

(ii) Lateritic Iron-ores.

The detrital laterite passes locally into lateritic iron-ore by increase in the percentage of iron oxide. Such iron-ores are well developed along the inner margin of the coastal plain encircling the Colony, and occur principally in the neighbourhood of Devil Hole, near Waterloo. They were derived originally from the magnetite (titanomagnetite), which is such an important constituent of the norite mass forming the Colony. They were accumulated at an earlier period in the same way as black sands are accumulating on the coast to-day. The sea formerly reached as far as the inner margin of the present plain, and as the streams brought down the products of weathering from the hillsides the grains of iron-ore were deposited principally near the shore, and the lighter minerals, chiefly felspar and weathered ferromagnesian crystals, were carried further out, to build up the plain as now existent. Consequently the beds near the old shore-line contain a higher proportion of iron than those distant from it, and are sufficiently rich locally to rank as iron-ores. The ores have attained their present condition through the oxidation and hydration of a great proportion of the titaniferous magnetite.

The grade and structure of the ores vary considerably. The common variety is pisolitic; the cores of the pisoliths are black and deep red, the enclosing part red, and the interstices between the pisoliths are more or less filled with limonite. Another variety is finely mottled in purple, red, and yellow, and shows only a slight development of the pisolitic structure. The richest ores are made up of nodules or small masses of almost unaltered titaniferous magnetite, whereas the poorest ores are concretionary and contain only a low percentage of iron, chiefly in the form of thin limonitic coatings to the concretions.

A fragment of ore exposed on the surface of the ground weathers into a rounded nodule, and assumes a smooth polished ferruginous skin of a dark-brown colour.

The Devil Hole ores form a belt 400 to 500 yards wide, running parallel with the foot of the hills; the belt has been traced for three miles, and probably extends over a much greater distance. Several small shafts and a trench 15 yards long were excavated in the deposit with the help of explosives: the sections showed soil and subsoil up to 15 inches in thickness, passing downwards into a rubble containing large and small coarsely porous lumps. Underlying the rubble were large masses of a compact ore, which locally assumed an irregular platy structure. The ore was proved to a depth of 8 feet, and it probably continued to a much greater depth; there are thus well over 3,000,000 tons of ore indicated in this deposit. The deposit runs parallel with the Sierra Leone Government Railway, and is practically adjacent to it; moreover, since it is separated from the mouth of the Bunce River only by a narrow strip of the plain, about a quarter of a mile wide, the ore could be shipped directly at very little cost.

Mr. G. F. Scott Elliott [1] gives the following analysis of a sample of the ore from this district ("the hills behind Sierra Leone"):—

Protoxide of iron	70·62
Peroxide of iron	11·10
Titanic peroxide	14·10
Chromium peroxide	·15
Manganese peroxide	·20
Silica and silicates	10·31
Sulphur	·03
Phosphorus	·04
Lime	·02
Moisture	1·25
Oxygen and loss	2·18

Other analyses [2] of representative samples show that the amount of titanium they contain varies from 3 to 20 per cent, and since, under present conditions, steel cannot be made at a profit from

[1] Col. Rep. Misc., No. 3 (Sierra Leone), 1893, p. 6.

[2] Kindly made for the Geological Survey by the Wigan Coal and Iron Company, Ltd.

iron-ores containing more than 3 per cent of titanium, there is no immediate prospect of a demand for these ores.

5. Lateritization as a Factor in Cave Production.

There are many small caves and subterranean watercourses in the colony, due to the removal of unconsolidated sand from beneath a hard crust of laterite, and streams are known suddenly to appear and disappear, much as they do in limestone districts. Hart's Cave near York, and Devil Hole, near Waterloo, are the best-known instances of these phenomena.

Hart's Cave opens out on to the foreshore and runs back into the cliff for about 100 yards; it is about 35 feet in average width, and some 12 feet high, and owes its origin to a stream which runs its whole length and issues at its mouth. The stream has washed out the soft sand filling a trough in the norite, which outcrops along the foreshore, and left the hard, lateritic crust above standing as a roof.

The entrance is relatively small, and has been artificially reduced by a stone wall built half-way across it.

Devil Hole is a swallow-hole a few hundred yards to the north-east of the flag station of that name. It is a more or less cylindrical pipe in the laterite, 25 feet deep and 6 to 8 feet wide, and it opens out on the coastal plain at a height of nearly 100 feet O.D. Leading away in different directions from the bottom of the pipe are several low passages, which were dry when examined early in the dry season.

Caves are sometimes formed in the lateritized talus slopes of the steep seaward flanks of the mountains; the exposed outer layers harden into a crust strong enough to support itself when those below subside or are washed out. When the crust itself collapses wide-open caverns are formed, like those seen on the hill-side above the railway station at Waterloo, and that in the Babadori Valley, below Hill Station.

6. Summary.

1. Lateritization has been found to affect a variety of rocks in Sierra Leone, including norite, granitic rocks, and detrital deposits.

2. The norite of Sierra Leone is not deeply lateritized except in highly jointed areas or in certain bands readily susceptible to the alteration. It yields a gibbsitic laterite. A core of unaltered norite is enclosed in a light-coloured halo ("zone of leaching" of Professor Lacroix), which passes gradually into a red-brown laterite ("zone of concretion"). The transition from core to laterite is a rapid one. The minerals of the norite are attacked in the following order: felspar, diallage, hypersthene, magnetite (titanomagnetite).

3. Norite containing only a small quantity of disseminated magnetite is less readily lateritized than norite containing a moderate amount. Where, however, the norite includes an unusually high proportion, as in the streaks of magnetite, lateritization proceeds very slowly.

4. The granitic rocks of the Protectorate are frequently lateritized to a depth of 15 feet, and sometimes even to 30 feet. Nevertheless laterite is only slightly developed in the inselberg mountain districts of the northern part of the country. Lateritization of granitic rocks proceeds as follows: the rocks decompose into a white kaolinitic product, which passes into brown lateritic clay ("zone of leaching"); this lateritic clay then develops into laterite ("zone of concretion"). There is a progressive change from the unaltered rock to the laterite crust, the granitic rocks in this respect presenting a marked contrast to the basic rocks.

5. Lateritization affects detrital deposits also, particularly the Pleistocene sands and clays of the coastal plain. The phenomenon is most pronounced in the felspathic sands and diminishes in the more argillaceous beds until it is practically non-existent in pure clay. The typical lateritite is a red-brown scoriaceous rock, moderately hard, and in the hand specimen coarsely porous. It forms a crust about 10 feet thick at the top of the Pleistocene beds. This lateritite is indistinguishable from the laterite derived from other rocks.

6. The scoriaceous laterite (lateritite) was produced by the growth and ultimate coalescence of numerous small ferruginous concretions, followed by the removal of the soft material between the concretions.

7. The laterite formed from detrital deposits passes locally into lateritic iron-ore by increase in the percentage of iron oxide. Such iron-ores are well developed along the inner margin of the coastal plain encircling the colony, and occur principally in the neighbourhood of Devil Hole, near Waterloo. They were derived originally from the titanomagnetite which enters largely into the composition of the norite, and they are consequently very rich in titanium.

8. Lateritization is frequently an important factor in the production of caves and subterranean channels, owing to the ease with which the unconsolidated material is removed from beneath the thick hard crust of laterite.

In conclusion, I have great pleasure in recording my indebtedness to Professor A. H. Cox, of University College, Cardiff, who kindly made many useful suggestions during the writing of these notes.

EXPLANATION OF PLATE III.

Fig. 1.—Lateritized norite, in railway cutting, Wilberforce, Sierra Leone. The photograph illustrates a late stage in the lateritization of two blocks of norite. Each block is now represented only by a core of unaltered norite enclosed in concentric shells of laterite. The original upper surface of the right-hand block is indicated by the position of the hammer.

Fig. 2.—Residual laterite derived from granite, railway cutting near Baoma, Sierra Leone. The unaltered granite forms a ridge which traverses the cutting obliquely from right to left.

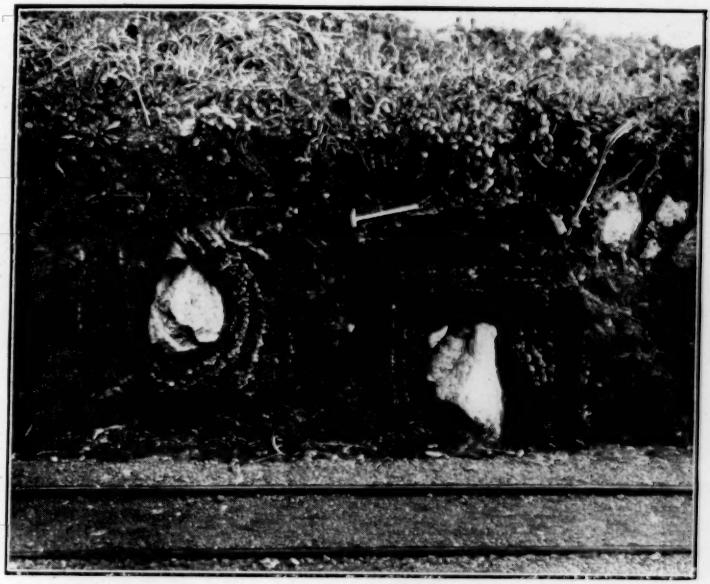

FIG. 1.—Lateritized norite, Wilberforce, Sierra Leone.

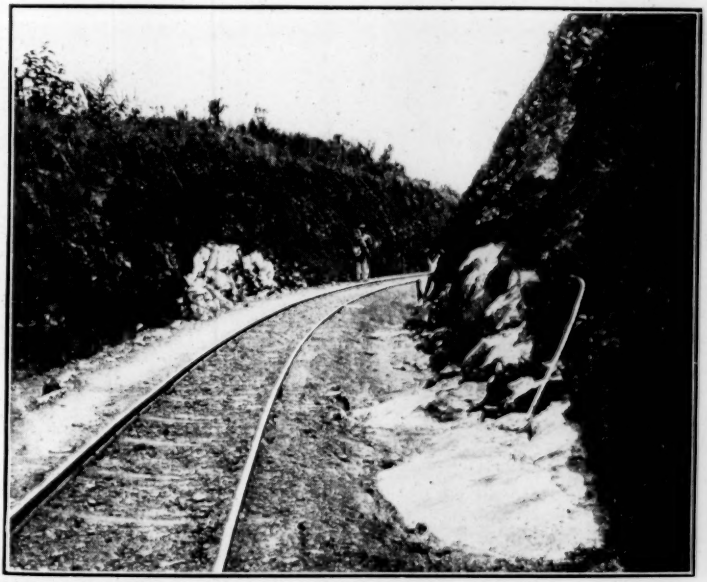

Photo. F. Dixey.

FIG. 2.—Residual laterite derived from granite, Baoma, Sierra Leone.

To face p. 220

The Geological Age of the Earliest Palæolithic Flint Implements.

By J. Reid Moir.

THE investigations which I have carried out in the Ipswich district of Suffolk, and certain discoveries (to be described shortly) made during the past year at Mundesley, Norfolk, have impressed upon my mind the possibility that the ordinary platessiform and batiform palæolithic flint implements found usually in river terrace gravels are older geologically than has been generally imagined. This, however, is not altogether an original opinion, as the late Professor James Geikie, F.R.S.,[1] the late Mr. S. B. J. Skertchly,[2] and Mr. A. S. Kennard,[3] basing their views upon evidence other than that upon which I rely, arrived at a similar conclusion. As is well known, it was stated authoritatively many years ago that our English river-valleys containing implementiferous gravel beds were cut through, and are therefore later than the Chalky Boulder-clay.[4]

Now, however, a closer examination, or access to sections not visible years ago, has demonstrated that in the case of the main river-valleys of Suffolk this dictum no longer holds good.[5] Further, it would appear hardly justifiable to assume that because a gravel bed can be shown to have been laid down after the deposition of the Chalky Boulder-clay, the flint implements contained in such a gravel, which are often considerably rolled and older than the bed in which they occur, are, necessarily, to be referred to post-Chalky Boulder-clay times.

Again, for many years past Continental archæologists and geologists have recognized that the various races of palæolithic man lived in mild epochs intervening between the different glacial episodes, and, as England during the greater part of the palæolithic period was joined to the Continent and experienced probably similar vicissitudes of climate, it would seem unlikely that all the English palæolithic artefacts are post-Glacial.

The discoveries to which I have referred have led me to propose the following table, showing the various prehistoric flint cultures and their relationship to the glacial deposits of East Anglia. I have also ventured to attempt a correlation of these East Anglian glacial deposits with those recognized upon the Continent by Professor Albrecht Penck.[6] But this is, at present, a tentative correlation,

[1] *The Great Ice Age*, pp. 520–46.

[2] *The Geology of the Fenland* (Mem. Geol. Surv. Great Britain).

[3] "The Pleistocene Succession in England": Proc. P.S.E.A., vol. ii, pt. ii, pp. 249–67.

[4] Sir J. Prestwich, Phil. Trans., vol. cl, 1869, p. 305.

[5] Boswell, "The Age of the Suffolk Valleys": Quart. Journ. Geol. Soc., vol. lxix, pp. 581–620.

[6] *Die Alpen im Eiszeitalter.*

and, further, I would wish it to be clearly understood that the views expressed in this note are based solely upon discoveries made in the Ipswich district, an area with which I am intimately familiar.

Neolithic.—On the high ground near Ipswich a flint arrow-head was found in the surface soil.[1] In the bottom of the Gipping Valley a chipped and polished flint axe has been discovered recently under 3 to 4 feet of peat surface soil. (*Man*, in course of publication.)

Upper Palæolithic: *Magdalenian.*—No certain traces found, unless a floor in Ivry Street, Ipswich, buried under 2 or 3 feet of stoneless snuff-coloured sand, can be referred to this cultural phase. This floor is situated upon the plateau.[2]

Solutrian.—A patinated and rolled early Solutrian flint blade was found in gravel at the site of the Ipswich Electric Power Station, situated in the bottom of the Gipping Valley.[3]

Two Early Solutrian blades were found in hill-wash overlying the Aurignacian floor in Messrs. Bolton & Co.'s brickfield, Henley Road, Ipswich.[4] This hill-wash was probably laid down during a period of low temperature, and may perhaps be regarded as the equivalent, on the high ground, of the river-gravel in the Gipping Valley containing a Solutrian blade. The period of low temperature responsible for these depositions may have been that known upon the Continent as the *Würm*.

Aurignacian.—A well-marked floor, containing Aurignacian flint implements, covered by the above-mentioned hill-wash, and resting upon loamy sand in Messrs. Bolton & Co.'s brickfield, Ipswich.[5]

Lower Palæolithic: *Upper Mousterian.*—A well-marked floor, containing Upper Mousterian flint implements, generally covered by peat or loamy sand, *and resting sometimes upon Chalky Boulder-clay* in Messrs. Bolton & Co.'s brickfield, Ipswich.[6]

? Middle Mousterian.—A floor with ? Middle Mousterian flint implements and abundant remains of reindeer, occurring in loam, and under 4 feet of alluvium and 8 feet of gravel (the deposit containing the Early Solutrian blade above mentioned) at the site of the Electric Power Station, Constantine Road, Ipswich.[7]

Lower Mousterian.—Flint implements found in Chalky Boulder-clay at Bolton & Co.'s brickfield, Ipswich, and Mason's Cement Works, Claydon.[8]

The Chalky Boulder-clay may be referable to the *Riss* glaciation.

[1] Moir, Journ. Roy. Anthr. Inst., vol. xlvii, 1917, pp. 406–7.
[2] Moir, Proc. P.S.E.A., vol. i, pt. iv, pp. 475–9.
[3] Hancox, Proc. Suff. Inst. Arch. and Nat. Hist., vol. xi, pt. i and pt. ii, fig. 4.
[4] Moir, Journ. Roy. Anthr. Inst., vol. xlvii, 1917, pp. 405–6.
[5] Ibid., pp. 367–412.
[6] Ibid.
[7] Moir, *Man*, vol. xviii, No. 7, July, 1918.
[8] Moir, Proc. Suff. Inst. Arch. and Nat. Hist., vol. xvi, pt. ii, pp. 98–134.

Acheulean.—Late Acheulean flint implements found by Miss N. F. Layard in a silted-up channel in the plateau at Foxhall Road, Ipswich.[1] One such specimen (now preserved in the British Museum, Bloomsbury), recovered by me on the eastern side of the channel, occurred upon sand overlain by contorted material classed by Boswell as "Upper Glacial".[2]

Chellian.—Small *derived* specimens of Chellian, platessiform implements were found in the Middle Glacial Gravel at Bolton and Co.'s brickfield, Ipswich.[3]

This gravel may perhaps be regarded as of *Mindel-Riss* interglacial age.

The discoveries made upon the Mundesley coast, and further researches carried out this year at Cromer, tend to show that the glacial gravels overlying the Till contain derived Chellian flint implements, and from the finding of certain flakes, etc., in the Cromer Forest Bed it is suggested that this deposit is the real Chellian horizon. The Till and associated beds may possibly represent the depositions of the *Mindel* glaciation. The Chellian implements may therefore be of *Günz-Mindel* interglacial age.

Pre-palæolithic.—The flint implements found in the detritus-bed beneath the Red Crag of Suffolk.[4] These specimens, which I regard as of pre-Chellian types, are frequently striated. It is possible that these striæ were imposed during the *Günz* glaciation (the earliest glacial epoch recognized by Penck), and the large block of dark-red porphyry, "weighing about a quarter of a ton," seen by Prestwich to be resting upon the London Clay at the base of the Coralline Crag at Sutton, near Woodbridge,[5] may have been transported by the ice of this glacial episode.

The very primitive edge-trimmed stones, known as "eoliths", occur as deeply iron-stained and rolled derivatives in the Middle Glacial Gravel in Messrs. Bolton & Co.'s brickfield, Ipswich.[6]

These specimens are regarded as representing the earliest efforts of man to fashion flints, and as being the precursors of the Sub-Red Crag artefacts.[7]

It is also believed that the Sub-Red Crag rostro-carinate flint implements developed into the earliest platessiform and batiform Chellian implements.[8]

The discovery of Acheulean flint implements at Hoxne[9] and at Foxhall Road, Ipswich,[10] occurring in deposits resting upon Boulder-

[1] Journ. Roy. Anthr. Inst., vol. xxxiii, 1903.
[2] Proc. Geol. Assoc., vol. xxv, pt. iii, p. 136.
[3] Moir, Journ. Roy. Anthr. Inst., vol. xlix, 1919, pp. 74–93.
[4] Moir, Proc. Prehis. Soc. East Anglia, vol. i, pt. i, pp. 17–43, and other papers.
[5] *The Structure of the Crag-beds*, London, 1871, p. 117.
[6] Moir, Proc. P.S.E.A., vol. i, pt. iii, pp. 307–19.
[7] Moir, *Pre-palæolithic Man*, pp. 21–34. Harrison, Ipswich.
[8] Moir, *Phil. Trans.*, B, 1919, p. 209.
[9] Brit. Assoc. Report, 1896, p. 12.
[10] Journ. Roy. Anthr. Inst., vol. xxxiii, 1903.

clay, are of importance in this inquiry (it seems that there are two glacial deposits at the latter place, one above the palæolithic horizon and one below it), and it is suggested that, at both these places, occur patches of a once widespread sheet of glacial clay older than what is known as the Chalky Boulder-clay, and perhaps referable to the *Mindel* glaciation. The well-known section at High Lodge, Mildenhall, where a Mousterian brick-earth interdigitates with a mass of Chalky Boulder-clay,[1] represents probably a remnant of the Mousterian deposits, many of which were ploughed up by the ice and furnished the implements of this culture found in the Boulder-clay.

Professor J. E. Marr, F.R.S., who has visited Ipswich and seen and examined the evidence at my disposal, permits me to say that he considers a prima facie case has been made out for the above correlation, so far as the deposits of East Anglia are concerned. He considers, however, that the reference of certain deposits to the periods of glaciation upon the Continent requires further investigation. With this conclusion I am in agreement.

On the Occurrence of Picritic Serpentine at Ebbor, near Wells, Somerset.

By Sidney H. Reynolds, M.A., Sc.D., Professor of Geology in the University of Bristol.

In October, 1904, Mr. H. E. Balch, of Wells, forwarded some pieces of "trap" from Ebbor to the late Mr. H. B. Woodward, who handed them to Dr. J. S. Flett for examination. At a slightly later date pieces were given to me by Dr. T. F. Sibly, who was then at work in the Mendips.

It was at once clear that we had here an ultra-basic rock, and Dr. Flett, whose description will be quoted immediately, pointed out the practical identity of the rock with that from Clicker Tor, Menheniot, Cornwall, whence he believed the specimens had been derived. The rock occurred in the form of small pieces, rarely more than 2½ inches long, scattered over quite a limited area about a quarter of a mile N.W. of Wookey Hole and due south of Lammas Wood. The very great majority were found in a field due south of Lammas Wood, a few pieces were found in the next field to the west, and one in the adjacent field to the east. The area lies slightly below the 400 ft. contour-line. The pieces are all fairly angular and comparatively little weathered. Probably over 200 pieces of the rock have been found here from time to time; on December 18, 1906, I myself found twenty-one pieces scattered over a small space in the central part of the eastern third of the chief field. I have found others on subsequent occasions, but for some years now have not been able to find any more. Mr. Balch, however, reports

[1] Sturge, Proc. P.S.E.A., vol. i, pt. i, pp. 43–105.

finding a piece in 1914. No pieces have been detected in any of the neighbouring walls, and the neighbourhood has been so carefully examined that if the rock occurred in situ it could scarcely fail to have been found.[1]

The country rock forming the fields where the picritic serpentine occurred is the Dolomitic Conglomerate, and another possibility which suggested itself was that we might be dealing with a pre-Triassic intrusion, and that the pieces found were pebbles in the Dolomitic Conglomerate.[2] To test this the Dolomitic Conglomerate was exposed by means of trial-holes at a number of points in the principal field, but no fragments of picritic serpentine were ever found.

The only remaining alternative to account for the presence of the rock is that it was brought from a distance and presumably from Menheniot. The suggestion that it was brought by human agency may, I think, be dismissed. Another explanation, and perhaps the most probable, was suggested in conversation by Professor Bonney, viz. that the pieces were derived from an ice-borne boulder.

The acceptance of this theory implies great submergence of the South of England, as the pieces occur at a height of 375–85 feet above Ordnance datum. It may, however, be recalled that Dr. J. V. Elsden[3] in 1887 described a granite boulder from Kithurst, in Sussex, which was found at the 600 ft. contour-line at the summit of the Chalk escarpment. The transport of material probably from Cornwall, which this theory involves, is also perhaps a difficulty, as the great majority of the foreign boulders on the south coast of England, which appear to owe their presence to floating ice, seem to have come from the north-east.[4] On the other hand the erratic blocks collected by Mr. Clement Reid from the Pleistocene deposits of Selsey, included rocks which reminded Professor Bonney[5] of types met with in Brittany, and one specimen was probably of Cornish origin. It is not, however, necessary to assume that such a submergence took place in Pleistocene times; the height at which the pieces of picritic serpentine were found is very much that of the platform rising to the 430 ft. level, which has been recognized along much of the southern part of the British Isles, from Ireland, through

[1] Mr. Balch, however, writes (June 14, 1914): "I am not at all convinced that the ice transport theory can hold. . . . I am strongly inclined to suspect an intrusion, small and so far not detected."

[2] This is the explanation suggested in a paper by the author read before the British Association at York in 1906 (Trans. of Section C, p. 581). There is also a brief account of the rock in the author's *Geological Excursion Handbook for the Bristol District*, 1912, p. 119. Mr. Balch shows the area in which the picritic serpentine was found in his *Wookey Hole*, pl. vi.

[3] Quart. Journ. Geol. Soc., vol. xliii, 1887, pp. 649–51.

[4] R. A. C. Godwin-Austen, Quart. Journ. Geol. Soc., vol. vi, 1850, p. 88. J. Prestwich, ibid., vol. xlviii, 1892, pp. 295–8. G. Barrow, *The Geology of the Isles of Scilly* (Mem. Geol. Surv., Sheets 357 and 360), p. 24.

[5] Quart. Journ. Geol. Soc., vol. xlviii, 1892, p. 351.

South Wales, to Devon and Cornwall, and which is generally attributed to the work of the Pliocene sea.[1] The suggestion is therefore made that the picritic serpentine is derived from a boulder dropped from an iceberg floating in the Pliocene sea.

Dr. J. S. Flett's description of the specimens sent to Mr. H. B. Woodward by Mr. Balch is as follows :—

"Augite Picrite, passing into serpentine."

"The hand specimens have a dark green colour and a smooth fracture, with slightly unctuous feel. The microscopic section shows that the rock consists mostly of rounded grains of olivine, decomposing into aggregates of yellow and green serpentine. These are partly embedded in or surrounded by irregular plates of pale brown augite, evidently of later formation than the olivine, on which it is to some extent moulded. Olivine forms at least one-half of the rock, and hence typical lustre mottling is not developed. A little secondary hornblende is also present. In all its features this rock is identical with the picrite of Clicker Tor, Menheniot, Cornwall, from which it has probably been derived."

The silica percentage as determined by Mr. E. M. Lane in 1906 in the chemical laboratory of University College, Bristol, is 30·66. The specific gravity as determined both by Mr. E. M. Lane and Mr. F. S. Wallis is 2·71, the relative lowness being no doubt attributable to the weathered character of the rock.

[1] See Barrow, Quart. Journ. Geol. Soc., vol. lxiv, 1908, p. 384.

REVIEWS.

THE PRINCIPLES OF ECONOMIC GEOLOGY. By WILLIAM HARVEY EMMONS, Ph.D. pp. xviii + 606, with 210 text-figures. New York: McGraw-Hill Book Company, Inc. London: Hill Publishing Co., Ltd. 1918. Price 24*s.* net.

IN this book the author presents a perspective of the present position of the scientific knowledge of metalliferous and non-metalliferous mineral deposits, with the exception of fuels and oil. However, the amount of space devoted to the non-metalliferous deposits amount to only about 70 pages out of 600, and it is to all intents and purposes a textbook of the geology of metalliferous mining. The first twenty-one chapters of 290 pages are devoted to a discussion of general principles, while the rest of the book is occupied by descriptions of actual occurrences, classified under the headings of the various metals or non-metals.

This is perhaps scarcely the place to discuss the general question of the rival classifications of ore-deposits, genetic or chemical; nevertheless it may be allowable to point out that the method here adopted presents many practical advantages, and certainly makes reference easy. A genetic classification, such as has been adopted in most of the larger German books, is perhaps more strictly scientific, but it is certainly confusing to the learner, since it brings together a whole lot of deposits which have little in common from the point of view of the miner and metallurgist, however similar their origin may be. On the other hand, an arrangement by metals groups in one chapter or section deposits that may have been formed in a great variety of ways, and a special difficulty presents itself in the case of ores worked for more than one metal. It is clear that an ideal classification has not yet been evolved, and from the nature of the subject it probably never will be. The whole matter is a question of the balancing of advantages and drawbacks, and in our opinion Professor Emmons has acted wisely in choosing as he has done.

The earlier chapters afford an admirable discussion of the general geological, mineralogical, chemical, and physical principles underlying the formation of workable mineral deposits. The metalliferous deposits are classified under eight headings, as magmatic segregations, pegmatite deposits, contact-metamorphic deposits, deposits of the deep vein zone, deposits formed at moderate depths by hot solutions, deposits formed at shallow depths by hot solutions, deposits formed at moderate and shallow depths by cold and meteoric solutions, and sedimentary deposits. This subdivision seems somewhat elaborate; it is very doubtful, for example, whether any real distinction can be drawn between pegmatites and veins of the deep zone, and it is well known that certain pegmatite dykes can be followed laterally or vertically into ordinary quartz veins, as indeed is explicitly admitted by the author, who also recognizes clearly

that most of his groups grade into each other by imperceptible transitions. The whole question really hinges on the extent to which the circulation of meteoric waters has taken part in the processes of ore-formation, and as is generally known more importance is assigned to this agency in America than in Europe, perhaps mainly owing to the influence of Posepný. In many American writings there are still strong evidences of the survival of the lateral secretion theory of Sandberger, and indeed something very like it is generally put forward in explanation of the origin of the lead-zinc deposits of Missouri and Kansas. Still more common is the conception of vein-formation by downward movement of meteoric waters into a region of high temperature where metals are dissolved and carried to a higher level by subsequent rise of the heated solutions. Acceptance of this theory is rendered difficult, amongst other evidence, by the fact that many deep mines are dry in their lower levels. The common occurrence of distinct ore-zones around and above intrusions is also difficult to explain on this hypothesis. These questions are discussed at length by Professor Emmons, who gives a most interesting summary of the divergent views on the subject, with a statement of the arguments for and against each of them.

A whole chapter is devoted to a detailed discussion of the superficial alteration and secondary enrichment of ore-deposits, so important from the practical point of view. Although the general underlying principles are well understood, certain points are still in need of explanation; it is still somewhat uncertain whether chalcocite and some other sulphides are ever truly primary, although the balance of evidence from observation suggests that they are. The whole process of oxidation, solution, and reprecipitation obviously depends on the chemical and physical conditions prevailing in the different regions of the ground-water, but the chemical changes involved are very complex and not yet fully elucidated.

The second and larger part of the book consists of descriptions of actual occurrences of minerals of economic value. These are very clear and effective, but it is perhaps admissible to remark that in this section a certain want of balance is shown. Descriptions are given of many American deposits of little economic value and still less scientific interest, while the important mining regions of other parts of the world receive scant attention. It may be suggested with all due deference that the object in view would have been better attained by treatment of a smaller number of examples, culled from all parts of the world and selected so as to illustrate general principles. Thus the student of economic geology, for whom the book is primarily intended, would acquire a better sense of proportion and learn to appreciate more fully the scientific and commercial value of certain highly important types of mineral deposit which do not occur in North America.

R. H. Rastall.

A Review of the Reptilian Fauna of the Karroo System of South Africa. By S. H. Haughton. Trans. Geol. Soc. South Africa, vol. xxii, 1919, pp. 1–25, with 4 figs.

MANY of the reptiles described in this paper are of unusual interest, as they are forms identical with or closely similar to the progenitors of the mammals. The general nature of the reptilian fauna in each of the principal series of the Karroo system (namely the Dwyka, Ecca, Beaufort, and Stormberg) is described, and then the relationships of the Karroo reptiles are discussed. The author traces the changes which occur as we pass from the primitive *Pareiasaurus* to the much more mammal-like animals represented by the Theriodonta. In the former the bones of the back of the mandible are well developed, but as we pass upwards we find a gradual reduction in the bones of this region and a corresponding enlargement of the dentary, which in mammals comes to articulate with the squamosal. Meanwhile the palatal portions of the premaxilla and maxilla become enlarged, and each bone meets its neighbour in the middle line, just as occurs in mammals. Furthermore, it is shown that the changes which took place were not always in the direction of increased specialization, since the teeth in *Endothiodon* are all molar, the incisors and canines having been lost, while in *Prodicynodon* and *Diictodon* the incisors alone have been lost. There can be no doubt, however, that all these genera are derived from forms which had a typical heterodont dentition, like mammals. The author believes that the "law of irreversible evolution", whereby an organ once lost can never be regained, though it may be replaced functionally by another organ, is a principle of universal application, but why the possibility of reversion followed by persistence due to survival value should be ruled out is difficult to see. Indeed, the results of modern breeding experiments are not always in conformity with this so-called "law" or "principle".

The paper is of great interest to the student of evolutionism.

F. H. A. M.

Notes on the Pleistocene Fossils obtained from Rancho la Brea Asphalt Pits. Los Angeles County Museum of History, Science, and Art, Department of Natural Sciences, Miscellaneous Publications, No. 2. pp. 35, with 22 figures. Los Angeles, 1918.

THIS paper contains figures and descriptions of various fossil mammals of interest: of these the skeleton of the Imperial Elephant, which was $3\frac{1}{2}$ feet higher than any known modern specimen of *Elephas*, and that of the prehistoric Camel, an animal which, like the horse, originated in North America and then became extinct there, are specially noteworthy.

The skeletons of the animals which were trapped in the asphalt beds of Rancho la Brea and preserved in the oil are very remarkable, and it is interesting to note that the same process is going on at the

present day in the excavated pits, where rabbits and other animals stumble into the pools of oil and become engulfed. A photograph is reproduced of a jack-rabbit entrapped in this way.

F. H. A. M.

Imperial Sources of Potash.

(1) Sources of Industrial Potash in Western Australia. By E. S. Simpson. Geol. Surv. W.A. Bull. No. 77, 1919. (2) Potash Recovery at Cement Plants. By A. W. G. Wilson. Canada, Dept. of Mines, Bull. No. 29, 1919. (3) The Potash Salts of the Punjab Salt Range and Kohat; and Suggestions regarding the Origin and History of the Rock-salt Deposits of the Punjab and Kohat By Murray Stuart. Rec. Geol. Surv. India, vol. l, pt. i, 1919.

THE acute shortage of potash which made itself felt during the War stimulated a search for new sources throughout the Empire, and in the three publications cited above the results of some of the investigations then begun are now made public.

1. In the Western Australian Bulletin all the possible sources are fully discussed and methods of treatment suggested. It is found that although immense quantities of wood-ashes are available, the content of potash is in general so extraordinarily small that they are useless except as a local fertilizer. Among potash-bearing minerals the state resources of microcline, glauconite, jarosite, $KFe_3(SO_4)_2.3H_2O$, and alunite are described, and it is shown that, if necessary, very considerable supplies could be obtained. It is almost needless to say, however, that the inducement to develop such deposits has now vanished. A detailed account of the alunite deposits of Kanowna is given by T. Blatchford, and the results of an examination of seaweeds for potash and iodine made by I. H. Boas are also set forth.

2. Dr. Wilson has written a valuable summary of the problems, scientific and commercial, associated with the recovery of potash as a by-product in the Canadian Cement industry. Equipment for preventing the escape of flue-dust has already been installed in nineteen cement plants, and of these seventeen were erected with the deliberate purpose of recovering potash. The quantity of potassium salts carried out with the flue-dust varies in ordinary practice from 2 to 7 lb. per barrel (350 lb.) of cement. As the cement plants average an individual output exceeding 3,000 barrels per day, it is clear that thousands of tons of potash are saved annually, and a serious nuisance—due to the escape of dust—considerably abated.

3. A re-examination of the Indian potash deposits was undertaken by Dr. Stuart during the seasons 1915–17. It was found that the potash-salts occur in discontinuous lenticles and irregular foliæ, and that no continuous bed is likely to be discovered in

the Salt Range. "Where the foliation is of the nature of banding, bands of potash may persist for some little distance, but even then they will probably thicken and thin throughout their length. The prospects of obtaining potash in the Salt Range are, therefore, not promising, and it is not likely to be worked profitably except as a by-product of salt-mining." In Kohat potash has been detected in water dripping from a deposit in one locality only, and there it is condemned by its inaccessible situation.

While carrying out his investigation of the economic value of the potash deposits, Dr. Stuart made a number of observations on the saline deposits as a whole, and these he has interpreted and embodied in a most valuable paper on their origin and history. Briefly, it is suggested that the rock-salt of Kohat and the Punjab belongs to one great salt formation, and that the differences in character of the salt exposed from place to place are due to the successive exposure of different zones. The Kohat salt contains calcium sulphate and belongs to one of the lowest zones. Various transition zones are represented, until at Khewra salt which may have belonged to the kieserite- or carnallite-zone is encountered. It is impossible to make a complete analogy between the Stassfurt sequence and that of the Indian deposits, because the latter have been metamorphosed. The existing dip and strike of the saline bands are probably not those of stratification, but represent a foliation in a new and different direction. The patchiness and lenticular form of the potash-bands receive an adequate explanation, and the many puzzling phenomena of sequence and structure are fully accounted for if Dr. Stuart's views are correct. In the German and Alsacian deposits, when potash is once known at any horizon, it can be predicted with certainty over a wide area, but in India "no assertion can be made as to where a lenticle of potash will occur, or as to its dimensions or shape when located". The prospects of obtaining potash from the Salt Range are therefore, unfortunately, far from promising.

ARTHUR HOLMES.

REPORTS AND PROCEEDINGS.

GEOLOGISTS' ASSOCIATION.

February 6, 1920.

The President, Mr. J. F. N. Green, delivered an address entitled "The Geological Structure of the Lake District".

General disposition.

The Devonian concertina-folding. Manner in which it affects various rocks. Cleavage. Passage in the main volcanic area from zone of flow in the east to zone of fracture in the west, with concomitant disappearance of folds and development of thrusts. Continuation of the Devoke Water thrusts. The anticlinorium.

Ordovician folding. Simple character. Its importance and main lines.

Interference of the two systems.

Post-Carboniferous movements. The Wastwater fault. Consideration of the effects of faults in highly folded strata. Question of tear-faults.

March 5, 1920.—The President, Mr. W. Whitaker, F.R.S., in the chair.

"The Geology of the Cardiff District, with special reference to the Easter Excursion." By Professor A. Hubert Cox, M.Sc., Ph.D., F.G.S.

Geological history of the district. The general succession and structure. Continued instability and proximity to shore-lines. Effects thereof on the character and distribution of the Palæozoic deposits. The Armorican folding. The Coalfield Syncline and the Cardiff Anticline. The pre-Triassic surface. The Mesozoic unconformity and overlap. Great lateral variation of the Mesozoic rocks. The drainage system and recent deposits. Main scenic features.

"Supplementary Notes on Shooters Hill." By A. L. Leach, F.G.S.

I.—A section in London Clay.

II.—The Minerals of the Shooters Hill Gravel. Results of an examination by Mr. G. Macdonald Davies, M.Sc., F.G.S.

March 26, 1920.—The President, Mr. W. Whitaker, F.R.S., in the chair.

"The Geography and Geology of N.E. France and adjoining areas, with special reference to the War Zone of the Western Front." By Evan W. Small, M.A., B.Sc., F.G.S.

General features of the structural geography of France. The *massif-central* and its historical influences: the regions of the Langue d'oc and the Langue d'oil. The pre-Permian Armorican and Variscan highlands. The young folded mountains of the Alps and Pyrenees. The belted relief of N.E. France. The Cotswold–Langres syncline. Relation of structure and form in upland belts. The concentric scarps as natural defences. The geology of the Vosges and the Faucilles Mountains. The folded Jura and the tabular Jura. The Oligocene trough valley of the Rhine. The eastern frontiers of France in 1812 and 1914. The chain of fortresses. The mineral resources of Alsace-Lorraine. The Sarre coal-field. The Ardennes and beyond. The gorges of the Meuse and Moselle. The porphyroids of the Meuse Valley. Some examples of river capture. The Eocene lowlands of Flanders. The Chalk uplands of Normandy, Picardy, and Artois. The Jurassic inliers of the Boulonnais and the

Pays de Bray. The region round Paris. The battlefields of the Marne. The Aisne tablelands and the Chemin des Dames. A digression on Laon and some other French cathedrals. The battle fronts in Champagne and Argonne. The Côtes de Meuse, the Woëvre, and the St. Mihiel salient. Summary and conclusion.

Institution of Mining and Metallurgy.

March 18, 1920.—The President, Mr. H. K. Picard, in the chair.

"Tin and Tungsten Deposits: The Economic Significance of their Relative Temperatures of Formation." By W. R. Jones.

The tin and tungsten deposits of the world, occurring in situ, can be classified according to their mode of occurrence into five classes: I. Segregation Deposits; II. Contact-metamorphic Deposits; III. Pegmatoid Deposits (which include deposits in minor igneous intrusions, such as pegmatites, aplites, quartz-porphyries, and rhyolites); IV. Quartz Vein Deposits; V. Replacement Deposits.

Evidence is adduced to show that the Segregation and Contact-metamorphic Deposits were formed at higher temperatures than were the Pegmatoid Deposits; that the latter were formed at higher temperatures than were the Quartz Vein Deposits; and that the Replacement Deposits, if such exist, were formed at comparatively low temperatures.

The author believes that a study of the relative temperatures of formation of these deposits, and in particular of the Pegmatoid and Quartz Vein Deposits (which together are the source of the bulk of the world's supply of tin and tungsten minerals) will be found helpful in investigating the probable persistence or non-persistence of the ore-bodies in depth.

The world's tin and tungsten deposits have been classified and briefly described, and certain general conclusions are established therefrom. These conclusions appear to support very strongly two hypotheses advanced in this paper, namely that deposits in which cassiterite and wolframite occur in intimate association were formed in a lower temperature zone than were the bulk of the tin deposits free from wolframite, and that cassiterite is a higher-temperature mineral than wolframite.

On the assumption that these two hypotheses are correct, and supported by other evidence bearing on the strength, lateral continuity, and mineralization of the lodes and so forth, the author suggests that some of the deposits of Tavoy District, Burma, where cassiterite and wolframite occur in intimate association, will be found in depth to resemble the tin deposits of parts of Siam, of the Federated Malay States, and of Cornwall.

It is emphasized that this method of investigating the difficult problem of what obtains in depth in a new field is not intended to substitute, but to supplement, any other helpful evidence that may be available.

MINERALOGICAL SOCIETY.

March 16, 1920.—Sir William P. Beale, Bart., President, in the chair.

Arthur Russell: "On the occurrence of Cotunnite, Anglesite, Leadhillite, and Galena on fused lead from the wreck of the Fireship *Firebrand*, Falmouth Harbour, Cornwall." The specimens were obtained in 1846 from the wreck of the fireship *Firebrand*, which was burnt in Falmouth Harbour about the year 1780. They were found under the lead pump, most of which appeared to have been melted and mixed with charcoal, and consist of slag-like masses of lead, which has evidently been fused, and upon the surface and interstices of which are numerous well-defined and brilliant crystals of cotunnite and anglesite, and more rarely small crystals of leadhillite and galena. The cotunnite crystals, which are colourless and transparent with brilliant faces, are nearly always elongated in the direction of the *a* axis, and attain a length of 3 mm. The habit is somewhat variable owing to the very unequal development of the faces. The forms observed were 010, 001, 021, 011, 012, 101, 111, and 112. The anglesite crystals are of rectangular habit, and exhibit the forms 100, 001, 110, 102, 122, and 113. The leadhillite crystals, thin six-sided plates in shape, are of a brown colour and show the forms 101, 201, 101, 201, 112, 111, 112, and 111. The galena occurs in minute cubo-octahedra. An occurrence of cotunnite formed under almost exactly similar conditions has been described by A. Lacroix. Similar occurrences of lead oxychlorides at Laurium, and of leadhillite in Roman slags from the Mendip Hills, were referred to.—W. Campbell Smith: "Riebeckite-rhyolite from North Kordofan, Sudan." A rock found by Dr. C. G. Seligman at the base of Jebel Katul, 350 miles south-west of the Bayuda volcanic field was described.—Dr. G. T. Prior: "The Meteoric Iron of Mt. Ayliff, Griqualand East, South Africa." This meteoric iron, found about 1907, is a coarse octahedrite similar in character to Wichita County (Brazos River) and Magura (Arva). On polished and etched surfaces it shows nodules of graphite and triolite, and abundant cohenite crystals arranged parallel to the octahedral bands. It contains about 7 per cent of nickel.

CORRESPONDENCE.

GAULT AND LOWER GREENSAND NEAR LEIGHTON BUZZARD.

SIR,—I know that my colleague, Dr. Kitchin, has always found it difficult to believe that the fossiliferous limestone beneath the Gault at Shenley Hill can be in its original position, and it is well that he and Mr. Pringle should have undertaken an independent investigation of the sections. But I am certain that they have misinterpreted the evidence in supposing that the limestone has been

brought below the Gault by Glacial overturn. This is the only point which it concerns me to discuss at present, as the other issues raised in their recent paper in your pages all depend upon it.

With a much wider knowledge of the sections than I possessed in 1903, when the first account of the fossiliferous band was published by the late J. F. Walker and myself (Quart. Journ. Geol. Soc., vol. lix, pp. 234–65), I shall maintain that the description of the sequence and conditions then given was substantially accurate. Ever since that time I have taken the neighbourhood of Leighton Buzzard as my geological playground, revisiting the sections again and again, often several times a year and rarely missing a year, attracted by the fresh features disclosed in the extension of the great sand-pits and in new excavations. Hence, I have now seen the fossiliferous band at one time or another in a practically continuous section over 300 yards in length and 10 to 50 yards in breadth, from Garside's pit on the south to Chance's pit on the north. Yet I have not found in it the slightest trace of intercalated Glacial material or of Glacial disturbance. Moreover, having made a particular study of glacially transported masses in Yorkshire and other places, I am the less likely to have missed such evidence if it had been present. Also, on reference to my notebook, I find that in April, 1914, I saw patches of pale-pink gritty fossiliferous limestone, somewhat decomposed, associated with the breccia-band at the base of the Gault in the Miletree Farm pit (see Fig. 3 of my critics' paper), which lies outside the area of the supposed overturn; and similar material was lately visible in the same position in another section between this pit and Shenley Hill.

All the new features observed since 1903 have helped to confirm my original view of the sequence. Between 1904 and 1906 the easterly workings of the Garside's pit, now abandoned, disclosed new facts which are absolutely irreconcilable with the hypothesis of Glacial inversion. I mentioned some of these, in brief, in my report on the visit of the Geologists' Association to Shenley Hill in 1908 (Proc. Geol. Assoc., vol. xx, pt. vi, p. 475), and dealt similarly with the Grovebury sections (with which we are not at present concerned) in reporting on a later excursion to Leighton Buzzard in 1915 (Proc. Geol. Assoc., vol. xxvi, pt. v, p. 310); and as Dr. Kitchin knows, I have embodied a further description of them in a paper written just before the War and intended for publication at a convenient season. This paper will afford me an opportunity to deal in detail with the arguments of my critics. Meanwhile, it seems advisable that I should state at once my disagreement with their main conclusion, and show reason for believing it to be wrong.

Last year it chanced that I could not conveniently visit the sections, though I should have contrived to do so if I had been aware that my colleagues' investigation was then in progress. However, I have re-examined the pits twice during the past month, and am satisfied that the features with regard to the fossiliferous band have

remained without essential change, and that my critics and I are discussing the same facts in this particular.

Dr. Kitchin and Mr. Pringle rely for proof of the inversion almost entirely upon inferences drawn directly or indirectly from the fossils of the limestones and its associated strata. They infer that the fossils in question—certain brachiopods, lamellibranchs, crustacea, and echinoderms—cannot occur in place below the Gault. But if the stratigraphical evidence is convincing, as I believe it is, that at this locality they *do* occur below the Gault, the *a priori* inference loses all validity. I presume that no geologist will claim that our present knowledge of the range of these particular fossils is so perfect that it cannot be extended. In strata so sparingly and sporadically fossiliferous as the upper part of the Lower Greensand, we know as yet very little about the life of the period. Now, the Shenley section, as I believe, has slightly extended our knowledge; and, in the paper of 1903, my co-author and myself offered what I still hold to be a reasonable explanation of the unusual elements of the fauna. Our critics naturally lay stress upon their own side of the argument, and dismiss the admixture of Lower Cretaceous forms as 'derivatives' and as occurring, perhaps, in a limestone similar to the so-called 'Cenomanian' rock, but of different age, and brought into contact with it by the inversion. I hardly need express dissent from these inferences; they merge into the broader question of the supposed Glacial overturn. Let us consider what this hypothesis implies, and how far it runs contrary to probability.

1. The supposed 'Cenomanian' limestone, a gritty rock of peculiar aspect and composition (fully described in our paper of 1903), is unlike any other rock known in the district, and shows every indication of having been formed on the floor on which it now rests. My critics have sought for it above the Gault all along the foot of the Chalk escarpment, and acknowledge that they have sought in vain. They fall back upon an assumption that it may have occurred above the Gault in a vanished tract in the neighbourhood of Shenley Hill, and that it may have remained at the surface there until the hypothetical inversion in Glacial times. Yet it is only a few inches thick, and is for the most part quite fresh and unweathered.

2. In the same way the bed of loose glauconitic greensand, up to 5 feet thick, which I saw below the Gault, surrounding an upstanding crag of iron-grit, in the easterly part of Garside's pit before the working was abandoned in 1906 (see Proc. Geol. Assoc., vol. xx. p. 475), is supposed to have been overturned from the surface; yet it also, though so readily perishable, shows no trace of weathering.

3. The slab of Gault, greensand, and limestone supposed to have been overturned has proved to extend without visible disturbance over an area of not less than 15 acres, and it still has a thickness of about 18 feet in Harris's pit, which, therefore, must be accepted as the minimum for the whole slab before the overturn. Not a trace

of drift has been found beneath the mass. It is supposed to have been sliced off exactly at the base of the Gault, and, like a pancake, to have been tossed over cleanly back into its bed, without breaking and without entangling any extraneous matter. By this overturn, it is assumed that a thin band of limestone originally at the top of the Gault and a similar thin band of limestone and breccia at its base have been everywhere brought directly into contact within a belt never more than 2 feet thick, and usually less, as shown in Fig. 2 of my critics' paper. Glacialists have been accused at times of expecting too much from ice-sheets, but they have never expected such a feat as this.

4. Reason is shown in our paper of 1903 for believing that the thin irregular layer of iron-grit or ironstone which covers the lenticles of limestone, and to which they appear to owe their preservation, was in existence before the deposition of the Gault. The fresh evidence accumulated during my later investigations has, I think, placed this point beyond doubt. It is, of course, fatal to the hypothesis of my critics, and they are compelled to put forward the argument that the ironstone floors have been formed in Post-Glacial times, after the beds had been overturned, though they tacitly admit that the ironstone fragments between the floors are of pre-Upper Gault age, at least.

But I feel that it is really useless to enter into a lengthy verbal debate in this matter; the evidence speaks for itself in the whole section, and I will ask anyone who is doubtful upon it to make a personal examination of what is to be seen, even though the exposures visible at any particular time can hardly be expected to give the cumulative impression which I have received year by year in seeing one section after another. I feel sure that it will be found easier, on the spot, to believe in an extension of the range of the anomalous fossils than to believe that the bed had been brought into its present position through a gigantic inversion by glacial or other agency.

As regards the Gault, for the present I will only say that my colleagues may possibly be right in claiming that the Upper Gault alone is present under Shenley Hill, though there are several factors which call imperatively for a suspension of judgment in this matter, pending further investigation. I may be permitted to point out that in our paper of 1903 we explicitly stated that the Gault exposed at that time contained no discriminative fossils, and that the presence of the Lower Gault was inferred solely on the evidence of the fossils recorded by Jukes-Browne from a neighbouring pit. But whether Upper or Lower Gault, the statement that it is inverted runs counter to so many points of evidence recently considered in the field, that I have no hesitation in rejecting the supposition as unwarranted.

G. W. Lamplugh.

St. Albans.
April 5, 1920.

CRYSTALLIZATION-DIFFERENTIATION.

SIR,—Mr. H. H. Read's acquaintance with modern French literature is evidently thorough, and one is surprised that this acquaintance has not rendered him more apt at simile. He compares my dependence upon crystallization as an explanation of many features of igneous rocks with M. d'Astarac's dependence upon sylphs as an explanation of ordinary happenings. Unfortunately for his comparison, we know that magmas do crystallize, and equally unfortunately for his dependence upon liquid immiscibility we do not know that silicates unmix. Immiscibility is the petrologic sylph.

In fact, immiscibility is a sort of super-sylph. One sees two related and intimately associated rocks, and one remarks that they were evidently formed from a common magma by unmixing. Since nothing is known about unmixing in silicates, one is therefore relieved from the responsibility of any further thought in the matter. However, Mr. Read's last paragraph rouses some hope. He expects that my excessive advocacy of crystallization will lead some one to champion immiscibility. If this some one will analyse immiscibility from a theoretical standpoint, if he will then apply his results to silicate magmas and examine whether associated igneous rocks bear such a relationship to each other in chemical composition, in time and space relations, that they can or cannot be regarded as the result of immiscibility, he will have conferred a boon upon petrologists, whether a succeeding generation shall find his conclusions right or wrong. But no amount of setting up immiscibility as a sylph will advance petrology.

It is possible, of course, that I have overworked crystallization, but no one who has seen the spring break-up in one of our Canadian lakes could doubt that deformation of a crystal mesh must have important consequences in the case of igneous rocks as well. There one sees weakened and honeycombed bodies of ice under impact from other masses, locally compacted into a solid mass with the water squeezed out of the comb, elsewhere stretched, fissured, and traversed by streaks of open water. That more or less related features could develop below ground is not to be questioned.

Though Mr. Read's review is for the most part a series of objections they are nearly always generalities, and are only occasionally specific enough to be answerable. My method of deriving *some*[1] banded rocks by torsion of a crystal mesh would not, as he concludes, give rise to an orientation of the early crystals normal to the bands. It is in the filling of the lenticular spaces that free flow of liquid occurs, and such crystals as would become detached from the walls of the lens during this action would be carried along by the liquid

[1] I have elsewhere suggested that banded rocks may at times be formed as a result of intrusion of heterogeneous liquid (not immiscible liquids). "Later Stages of the Evolution of the Igneous Rocks": *Journ. Geol.*, Suppl. to vol. xxiii, 1915, p. 30.

and oriented parallel to the banding. The slight amount of rotation of crystals possible in the compacted part of the mesh would not be sufficient to orient them in any particular way. The action would, as a whole, give rise to bands showing flow-structure, therefore, and exhibiting the moderate contrast between bands that is normal in banded gabbro. The occasional ultra-basic bands of extreme contrast could also be developed as a further result, for in the larger lenses of liquid crystal sorting would occur under conditions particularly favourable to the production of monomineralic types.

Though apparently not himself a strong advocate of crystallization differentiation, Mr. Read appears to have some apprehension that the credit for originating certain ideas in that connexion might leak out of the Tight Little Island. He therefore points out that Darwin postulated crystal-settling seventy years ago, and in two places that Barrow postulated mechanical straining thirty years ago. Though Darwin needs no eulogy of mine or Mr. Read's, I too have pointed out Darwin's origination of the idea of crystal-settling,[1] and though I have not referred directly to Barrow's work, I have referred to Harker's discussion of it and similar work.[2] If I may be permitted, I would like to point out to Mr. Read that the assumption of immiscibility also dates back to Darwin's time, and that it is still an assumption—a sylph, if he prefers the term.

N. L. Bowen.

Kingston, Canada.
February 27, 1920.

OBITUARY.

Robert Etheridge (1847–1920).

Mr. Robert Etheridge, the son of the distinguished geologist and palæontologist of that name, died after a short attack of pneumonia at Colo Vale, near Sydney, on January 4, in his 74th year. Etheridge early took up geological work in Australia, as a member of the first Geological Survey of Victoria, under the direction of A. R. C. Selwyn, in the middle sixties. The survey having been disbanded as the result of a political crisis, young Etheridge returned home and was appointed palæontologist to the Geological Survey of Scotland, his father being then palæontologist to the English Survey. When the natural history collections of the nation were removed from Bloomsbury to the new Natural History Museum in the Cromwell Road, the two Etheridges were brought on to the staff of the Geological Department, where the memory still remains of the vigorous actions and language of "R. E. junior". The chief piece of palæontological work accomplished by Etheridge while in this

[1] N. L. Bowen, "Crystallization Differentiation in Silicate Liquids": *Am. Journ. Sci.*, vol. xxxix, 1915, p. 175.

[2] "Later Stages of the Evolution of the Igneous Rocks": *Journ. Geol.*, Suppl. to vol. xxiii, 1915, p. 14.